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This technical report is in three parts. Part I is a conceptual treatment of communication in which the human being is viewed as a goal-attainment system. The goal-attainment problem is defined as a discrepancy between the current state of the system and a specified goal state. Several forms of the communicative relationship are outlined. Part II describes a Task-Directed Learning (TDL) approach to communication training in which participants generate and critically examine their interpersonal communication in relation to selected measures of effectiveness in solving laboratory problems. Brief descriptions of problems and related materials (Vocom problems) are included. Part III summarizes objective performance data (time, error, and recall) for selected Vocom problems, and presents some informal suggestions for research in interpersonal communication. (Authors/MLF)

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TECHNICAL REPORT

Problems, Problem-Solving and Human Communication

A Laboratory Approach to Training In Interpersonal Communication

Prepared for the

Directorate of Information Sciences of the
Air Force Office of Scientific Research

and

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Educational Administration
(CASEA)

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ABSTRACT

Part I of this report proposes a conceptual treatment of communication in which the human being is viewed as a goal-attainment system. Signs and representations (symbols) are treated both as determinants and products of problem-solving behavior. The goal-attainment problem is defined as a discrepancy between the current state of the system and a specified goal state. Detecting and reducing the discrepancy requires solutions for designative, prescriptive and appraisive sub-problems. When problem-solving (a process of selection) is mediated by the semiotic behavior of another system, the systems are semiotically coupled, or interdependent. Several forms of the communicative relationship are outlined.

Part II describes an approach to communication training referred to as Task-Directed Learning (TDL). Participants generate and critically examine specimens of their own interpersonal communication in relation to selected measures of effectiveness in solving laboratory problems. Brief descriptions of TDL problems and related materials (Vocom Problems) are included.

Part III summarizes objective performance data (time, error and recall) for selected Vocom problems and presents some informal suggestions for research in interpersonal communication.

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PART I

PROBLEMS, PROBLEM-SOLVING AND HUMAN COMMUNICATION

F.L. Brissey and R.J. Hills*

Introduction

A properly naive observer scanning the full range of animal life on earth could scarcely fail to note that a particular species is set apart from the others by the degree to which its members engage in a form of behavior which they themselves refer to as communication. Furthermore, having made that observation, he could scarcely refrain, if sufficiently curious, from asking, "Why?" The answer typically given to this question by biologists, zoologists, paleontologists and the like, invokes the theory of evolution and the principle of nature selection. A superficial account might argue that when man's primate ancestors changed from a competitive, tree-dwelling herbivore living in loosely organized aggregrates, to a cooperative, ground-dwelling, predatory carnivore living in relatively more highly organized groups, any accidental developments in communicative activity provided an adaptive advantage which tended to insure the perpetuation of the more communicative species.

The adaptive advantage of being able to symbolize properties of the environment and to communicate in terms of those symbols is reasonably apparent. The lower animal's primary means of solving problems of adaptation seems to be the physical execution of relatively limited, largely pre-established behavioral sequences. The human animal, however, has been widely assumed to gain a tremendous advantage in being able to invent and manipulate signs and symbols standing for objects and events as well as their properties and relations (including man himself and his own actions). Symbols can be manipulated, it has often been claimed, as if they were the objects, properties, events and relations for which they stand, and if the symbols are chosen well the results of the symbolic operations will represent the results of the corresponding physical operations. The human animal, then, can assess the consequences of physical operations without actually performing them. As von Foerster has noted, "It is obvious that this saves considerable amounts of energy. But the really crucial point here is that errors in reasoning /symbol manipulation/ are not necessarily lethal." (von Foerster, p. 180)

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We might speak of the contrast between man and the lower animals in terms of the source of behavioral control. To a far greater extent than is the case for man, the behavior of lower animals is genetically controlled. "To build a dam a beaver needs only an appropriate site and the proper materials--his mode of procedure is shaped by his physiology." (Geertz,p. 7) But man, as he points out, "whose genes are silent on the building trades," must learn the process from the ground up so to speak; and having done so he is likely to preserve what has been learned in the form of symbolic representations of a dam, i.e., a blue print, a plan, a set of linguistic symbols, or a picture. Moreover, having learned to do this much, he can do still more, for he can construct representations of dams which don't exist, in valleys which occur nowhere on earth, to impound water which has not accumulated, to service populations not yet born, etc. In short, to a far greater extent than is the case for other species, and in one form or another, man's behavior falls under the control of symbols. It is not so much that his genes, his physiology, that determines his behavior, but the symbols he has invented or learned from others. Certainly it would seem that this remarkable capacity to represent the world symbolically and to share these representations with others should be of incalculable benefit in solving the problems of adaptation and survival.

However plausible this answer may be, it must surely present the observer with a paradox, for further observation may very well lead to the conclusion that the survival of the very species that is, by the above account, best equipped for survival has become at least as uncertain as the survival of less favored species. Moreover, there may be some reason to suspect that the very capacities that would seem to increase the probability of survival are responsible at the same time for decreasing that probability. Again the question, "Why?"

An indication of the direction in which a satisfactory answer to that question may lie is associated with the observation that for the beaver both the question of what to do (build a dam) and how to do it is answered genetically. For the human animal, however, the control of behavior in both contexts is heavily influenced by symbolic representations of man himself and his world. Symbols influence not only what men do to get what they want, but in considerable measure what they want as well. "Men, institutions and societies learn what to want as well as how to get, what to be as well as what to do; and the two forms of adaptation are closely connected." (Vickers, 1964,465-477)When what is wanted and how to get what is wanted are represented by marks on paper, engravings on stone tablets, or complex sequences of phonological events, there is no way of assuring that the wantings and the actings represented are related even indirectly to survival. When man deals with man symbolically, wants and acts inimical to his survival may appear to emerge, and even, at times, be mistaken for progress.

Our question, then takes the form of an inquiry concerning the nature of the symbolic process and its bearing on two issues of fundamental importance to the human being: what is to be wanted and how what is wanted is to be achieved. There is a sense in which these issues constitute problems to be solved whether by individuals or by groups and our inquiry therefore assumes the general form of seeking to understand the relation between problem-solving and the symbolic process. More specifically, the task we have set for ourselves is to provide tentative answers to the following questions: (1) What theoretically and empirically useful interpretation can we give to the proposition, "A has a problem?" By theoretically and empirically useful we mean an interpretation that both corresponds to empirical observations and is linked with a conceptual system. In this connection, it is our view that a sufficient degree of convergence has developed among several distinct intellectual orientations to suggest the formulation of a more integrated conception than is generally available in any single orientation. We have drawn, accordingly upon such diverse areas as the conception of goal-directed information-processing systems, principally the views of D.M. MacKay; operant conditioning, following B.F. Skinner; information theory, particularly the concepts of structure and uncertainty as treated by W. Garner; semiosis, or the theory of signs and symbols proposed by C. Morris; and, conceptions of the communicative process drawing particularly upon T.M. Newcomb but supplementing his formulation with those of the others and the present authors.

(2) What theoretically and empirically useful answer can we propose for the question, "What kind of problem does A have?" Two recent reviews of research in the area of group problem-solving have called attention to the fact that the problems employed in investigations of problem-solving vary from one study to another to such an extent that it is extremely difficult to formulate any generalizations about the process. In other words, the problem itself has not been treated as a variable in its own right, and there is but little conceptual development currently available to aid in systematically differentiating one problem from another. In commenting on the nature of tasks which have been employed in studies of group problem-solving, Hoffman writes:

> One of the foremost difficulties concerns the term "problem solving" itself. Problem solving has been used with reference to tasks as varied as judging the number of dots briefly displayed on the large card, to providing answers to arithmetic reasoning problems, to solving the complex problems faced by the managements of large business organizations. (Hoffman, 1965, p. 122)

Although the point is obvious, he feels, the matter has been neglected. "It calls for the systematic development of a taxonomy of problems." (Hoffman, p. 123) Our answer to question (2) will take the form of a preliminary taxonomy of problems based on the conceptual scheme within which we are working.

(3) What theoretically and empirically useful meaning can we give to the proposition, "A and B have a problem?" In our answer to this question we shall utilize the same conceptual machinery proposed in our answer to question (1).

(4) Finally, what theoretically and empirically useful interpretation can we provide for the *process of communication* in light of the analysis of problems and problem solving developed in connection with the preceding questions? In summary, it is our purpose to develop a general framework within which to examine the concepts of problems, problem-solving and interpersonal communication. At best we may succeed in identifying a few of the major landmarks in what has turned out (for us) to be an exceedingly complex territory. At worst we will have oversimplified and dangerously distorted a field of inquiry having vital significance for the human being. While we hope the former and dread the later, of one thing we are certain; understanding the human being demands an understanding of interperosnal communication.

A Conceptual Dilemma

Given the objectives outlined above, the inquirer is at once confronted with one of the classic issues of behavioral science, especially if the term *science* is to be taken seriously. By way of identifying this issue as sharply as possible, particularly as it bears on the questions guiding the present discussion, consider the following description of adaptive behavior provided by W. Ross Ashby in Design For A Brain:

> When a kitten first approaches a fire its reactions are unpredictable and usually inappropriate. It may walk almost into the fire, or it may spit at it, or it may dab at it with a paw, or try to sniff at it, or crouch and 'stalk' it. Later, however, when adult, its reactions are different. It approaches the fire and seats itself at a place where the heat is moderate. If the fire burns low, it moves nearer. If a hot coal falls out, it jumps away. Its behaviour toward the fire is now 'adaptive'. (Ashby, 1960, p. 12)

The author's problems were "...to identify the nature of the change which shows as learning," and, "...to find why such changes should tend to cause better adaptation for the whole organism." (Ashby, p. 12) What is to be said of the kitten's problem? As a first approximation it seems reasonable to suggest that the observer and the kitten both have a problem to solve, a practical problem in the case of the kitten and an intellectual problem in the case of its observer. In some measure, Polanyi's conception of problem-solving would seem to apply to both:

> There is a purposive tension from which no fully awake animal is free. It consists in a readiness to perceive and to act, or, more generally speaking to make sense of its own situation, both intellectually and practically. From these routine efforts to retain control of itself and its surroundings, we can see emerging a process of problem-solving, when the effort tends to fall into two stages, a first stage of perplexity, followed by a second stage of doing and perceiving, which dispells this perplexity. (Polanyi, 1957, p. 89)

However, the fact that one of the animals is a kitten raises the immediate question of how an observer might know about the kitten's initial state of perplexity and when the state has been dispelled. Despite the human being's willingness (at times) to provide reports of his puzzlement or uncertainty, some have urged that such reports be treated only as another form of observable behavior and not as evidence for what may be regarded as unobservable, private states.

> ...the task of modern psychology is to make sense of what people and animals do, to find some system for understanding their behavior. If we, as psychologists, come to this task with proper scientific caution, we must begin with what we can see and we must postulate as little as possible beyond that. What we can see are movements and environmental events. (Miller, *et.al*., 1960, p. 6)

The authors of the foregoing passage find a strict interpretation of such advice unduly restraining and express their own preference for theoretical approaches which are admittedly more speculative. (Miller, *et.al*., p. 11) There is no denying the appeal of these author's proposals for 'subjective behaviorism' and it is tempting to follow their lead in developing our treatment of problem-solving and communication.

On the other hand, we find Skinner's proposals for attending to external events as independent variables and observable behavior as the functionally related, or dependent variable to have an appeal of its own, (Skinner, 1953). In any case, given our objectives, it seems clear that to 'communicate' with those under observation as a means of obtaining data would provide only an ill-disguised form of question-begging; moreover, to deal in inferences that are not open to observational verification is to abandon our preference for approaching our problem as "natural scientists." In the beginning, at least, we have endeavored to approach the subject from the point of view of an observer and to be as alert as our resources allow to the assumptions which accompany this choice.

We, as others before us, have found the task to be extremely elusive simply because the processes under consideration provide a continuous and often subtle invitation to engage uncritically in the language of one participating in the processes under scrutiny. We do not feel that such excursions are objectionable in themselves, indeed they are quite probably necessary, at least in the context of discovery (Rudner, 1966). But we are impressed with the necessity of keeping as clear as possible about the differences between an observer's frame of reference and that of a participant; it is highly desirable, we feel, to avoid uncritical shifts from one position to the other despite our suspicion that both are essential to inquiry in some more complete sense of the term.

Thus, at the outset, we have tried to deal as nearly as we can with what can be observed and "to postulate as little as possible beyond that."

Communication and the Concept of Signs

In this portion of the discussion we are primarily interested in the concept of signs and how signs may mediate behavior, whether within or without the context of communication. It will be useful, however, to entertain a preliminary view of the communicative process in preparation for a more expanded treatment to be presented in a later section, and to suggest, somewhat approximately, the context in which the present treatment of signs is to be embedded.

It has been quite common to treat the process of human communication in terms of relationships holding among at least three and sometimes four "elements." Thus, one person is said to be the transmitter (source, encoder, sender, etc.) who conveys a message (signals, signs, symbols, etc.) to another person who is the receiver (destination, decoder, target, etc.); the events about which the message is said to have been composed constitutes the fourth element. The conception proposed by Newcomb is one of the better known examples:

> Every communicative act is viewed as a transmission of information, consisting of discriminative stimuli, from a source to a recipient. For present purposes it is assumed that the discriminative stimuli have a discriminable object as referent. Thus, in the simplest possible communicative act, one person (A)transmits information to another person (B) about something (X). (Newcomb,1953, p.393)

Given this description of the communicative act, the "message" consists of some behavior on the part of A which can serve as a discriminative stimulus for B but which also has some other source of discriminative stimuli (object) as referent. Thus, if B is to be "informed" by A's behavior, B is required to respond discriminatively both to the behavior of A and to the object which is taken as the referent.

By this treatment, stimulus events of one kind serve as a determinant of an individual's behavior with respect to something else; and it seems reasonable to regard events of the first kind as signs whether the stimuli in question are "physical events" or the behavioral properties of another organism. Moreover, if there are discriminable differences in the kinds of behavior which may be engaged in by B associated with discriminable differences in signs, then it would appear useful to classify the signs accordingly. Such an approach is distinctly reminiscent of the theory of learning proposed by Tolman some years ago in which signs, expectations and the confirmation of expectation played central roles. (Hilgard, p. 191-221). The discussion to follow will display an even closer similarity to Tolman's thinking. Perhaps the only important difference will be found in the present concern with the process of communication and the effort to treat the process in a rather stringently construed observer's language. This strategy leads (necessarily?) to a conception of behavior based on reinforcement theory. The present work may therefore be construed as an "objectivist theory of signs." But this is getting ahead of the story.

Newcomb's view of information as discriminative stimuli having a "discriminable object as referent" together with the suggestion that such stimuli may be referred to (alternatively) as signs is quite compatible with the theorizing of Morris under the general heading of semiotic, or the general theory of signs. We will return later to the concept of information, but for the present it will be useful to review Morris's "tridemensional theory of signification." (Morris, 1964, p. 7)

First, all action is seen as having to meet three requirements:

> The actor must obtain information concerning the situation in which he is to act, he must select among objects that he will favor or accord positive preferential behavior, and he must act on the selected object by some specific course of behavior. (Morris, 1964, p. 7)

Fulfilling these requirements may occur with or without the mediation of signs, but when signs are involved the process is referred to as semiosis. This is a five term relation in which a sign (v) sets up in an interpreter (w) a disposition to react in a particular way (x) to a certain kind of object (y) which is not then acting as a stimulus. The context in which these events occur (z) is the fifth term of the semiotic process. The disposition to react in a particular way (x) is referred to as the interpretant Recalling Newcomb's treatment of communication, we may suggest that when A's behavior "sets up" in B a disposition to react in a particular way to some other object (in a specified context), A's behavior is serving as a sign for B.

Given this initial formulation of the sign process, it must be asked at once whether the event referred to as "setting up a response disposition" is subject to a meaningful analysis in the observer's language. It's apparent that several quite different constructions may (and have been) imposed on the notion of response disposition. In the present context, we propose to treat the matter in terms of observable changes in certain characteristics of an individual's behavior such as the relative frequency or latency of specified behaviors.

Thus, the question of deciding whether A's behavior has influenced B's disposition to respond in some particular way to some other object is assumed to be a matter of determining, for example, what change has occurred, if any, in the probability that the response in question will occur.

As we have described the process thus far, the basic properties of semiosis are nicely illustrated in the operations described by Skinner in connection with establishing a discriminative operant in the behavior of an experimental animal. In fact, the parallel is sufficiently clear to warrant borrowing Ashby's strategy and use a typical operant learning situation as a "type problem" for the purpose of examining certain features of semiotic in greater depth.

Accordingly, our type problem may be described briefly as follows: a food-deprived animal is placed in an experimental space containing a light and a lever, or bar. Pressing the bar automatically triggers a food-dispensing mechanism. Thus, upon pressing the bar a pellet of food is made available for the animal's consumption. The essential conditions are described by Skinner as: (1) a stimulus (the light) which is the occasion upon which (2) a response (bar pressing) occurs and is followed by (3) a reinforcement (the food). Once acquired, the operant behavior is under the control of the stimulus insofar as the probability of the animal's behavior may be altered simply by presenting or withdrawing the stimulus. (Skinner, 1953) This description calls attention to a particularly important property of the stimulus - the behavior in question (bar-pressing) is _under its control_ and, therefore, the control of the light's controller. The elements of semiosis are easily traced in this situation. The controlling stimulus becomes the sign in response to which the animal engages in a particular form of behavior relative to something else, i.e., the animal presses the bar. The role of the light in this situation is unambiguous, but certainly stimuli, or signs, other than the light are functioning in the experimental space, and our problem is to propose what they may be and what functions they perform with respect to the animal's adaptive behavior.

In the foregoing example, the stimulus, or to speak semiotically, the sign achieved _control_ over one particular form of the animal's behavior. On the assumption that the animal could have engaged in any number of other acts than pressing the bar, we may say that the sign functions to _select_ certain acts from a set of alternative acts.

But bar-pressing is only one among a number of different behaviors displayed by the animal and meets only one of the functional requirements for adaptive action proposed by Morris. Thus, for example, the actor must also obtain information about the situation in which the action is to occur. (This is analogous to the X about which information is conveyed in Newcomb's conception of communication.) In the same sense that the light comes to "select" bar-pressing as an instrumental response, _designative_ signs function to select those classes of behavior which are referred to as _perceptual_. In this case, the interpretant is "... a disposition to react to the designated object as if it had certain observable properties." (Morris, p. 6) Presumably, the behavioral events referred to as signal detection, pattern recognition, stimulus discrimination, etc., would fall in the class of designative interpretants insofar as the occasion for their emission is the presence of a sign.

However, when a sign selects behaviors which operate on the environment in a manner that changes the properties of the environment, the relation of the interpreter to the environment, or both, the sign is functioning prescriptively. Thus, prescriptive signs function to select the forms of behavior referred to by Skinner as operants and "...the interpretant would be a disposition to act in a certain kind of way to the designated object or situation." (Morris, p. 6) The bar-pressing behavior of the animal in the preceding discussion of the discriminative operant is a clear example of an instrumental interpretant under the control of a prescriptive sign.

The analysis of the animal's action is still incomplete, however, for we must account for the selection and consumption of food in the situation under study, i.e., the animal's "preferential behavior." To the extent that signs may be involved in preferential acts, they function appraisively; thus, appraisive signs select those classes of behaviors which are commonly regarded as preferential whether "positive" or "negative." In this case, "...the interpretant would be a disposition to act toward a designated object as if it would be satisfying or unsatisfying" (Morris, 1964, p.6). A special problem arises in connection with providing a behavioral account of appraisive signs; i.e., how is the observer to determine whether any particular action toward an object is "satisfying" for the actor? From the point of view of an observer it can be determined that a particular event (a sign) is the occasion upon which an interpreter performs an act with respect to something else and that such an act is reinforcing, with respect to still another response. As Skinner has pointed out:

> The only way to tell whether or not a given event is reinforcing to a given organism under given conditions is to make a direct test. We observe the frequency of a selected response, then make an event contingent upon it and observe any change in frequency. If there is a change we classify the event as reinforcing to the organism under the existing conditions. (Skinner, 1953, p. 72-73)

In the example of the food-deprived animal discussed earlier, the act of consuming the pellet of food reinforces bar-pressing. Thus, an appraisive sign selects behaviors with respect to other objects or events (such as "eating a pellet of food") which changes the frequency of some other behavior's occurrence. This treatment of appraisive signs may appear somewhat circuitous to those accustomed to treating verbal reports of others as evidence for internal states of satisfaction, or inferring such states from other (non-verbal) behavioral "signs." Nevertheless, it appears to provide an account which is consistent with the rules we adopted at the outset.

It should be noted that in each case, an event of some kind (the sign) serves to designate some other object or event and selects (by our treatment) a particular form of behavior with respect to the designated object. Loosely stated, when the selected behavior is perceptual, the signs are designative; when the selected behavior is manipulative, the signs are prescriptive; and when the selected behavior is reinforcing, the signs are appraisive.

It will be recalled that the present treatment of signs was derived from a preliminary interpretation of Newcomb's assumption regarding the nature of information; i.e., information consists of discriminative stimuli which have a discriminative object as referent. We have proposed that signs function so as to select certain behaviors from a set of alternative behaviors. If we assume that the animal actually engages in a number of observable behaviors prior to training, and that those behaviors remain possible (in principle) following training, then the light conveys an amount of information to an observer which is related to the number of alternative behaviors that could occur.

If we assume that the animal can actually engage in a variety of observable behaviors with some known probability of doing so, and that upon the occurrence of the light one and only one of these behaviors actually occurs (e.g., bar-pressing), then an observer may report that the light conveys some amount of information related to the number and probability of behaviors that could occur. In other words, a sign conveys some amount of information depending on the extent to which the behaviors that could occur are reduced to some smaller set that actually occur. The guidelines are derived, of course, from the classic Shannon formulation of information. (Garner, 1962)

The present suggestions are reasonably consistent with Cherry's discussion of information as the logical equivalent of "instructions to select" a particular sign from an alphabet of signs (Cherry, 1957, p. 169). In principle then, under appropriate conditions an observer might determine both the kind of information (designative, appraisive or prescriptive) and the amount conveyed by a sign with respect to the behavior of a particular organism.

We will return to this question in the context of later discussion concerned more directly with human communication and the role of signs in that process.

Signs and Operants

In the discussion to this point we have proposed to treat the concept of signs in accordance with operant learning and with particular reference to discriminative operants. Once the operant behavior has been established (there is a high and stable probability that the animal will press the bar upon the presentation of the light) the light may function in each of the three dimensions of signification described by Morris. It may function as a designative sign insofar as the animal behaves toward the bar as if it had certain properties; but it may also function as a prescriptive sign in that the animal presses the bar, an act which is instrumental in securing food; and the light may also function as an appraisive sign in that the behavior involved in approaching and consuming the food is reinforcing. This analysis is consistent with Morris's suggestion that any event may function as a sign in each of the three modes of signification (although one may be predominant) as the light appears to do for the animal. It is very apparent that describing the animal's behavior in terms of the notion of signs adds nothing to the account already provided in simply describing the conditions required to establish the behavior in question. However, a more detailed examination of the animal's situation may reveal somewhat greater utility for the notion of signs than the analysis thus far might suggest.

First, we note that the light may be regarded as a variable with at least two possible states "on" and "off." Its states may also be perfectly correlated with the two possible states of another variable, the (extreme) positions of the bar, "up" and "down." At least we can imagine the experimental space to be so arranged that when the bar is pressed the light goes out and when the bar is released (and following a specified interval of time) the light turns on. In short, the relationships between the states of the two variables is "structured." It is also apparent that a similar structural relation holds between the two states of the bar and activation of the food-dispensing mechanism. Indeed, the experimental space must be structured in some fashion if the animal is to learn anything at all. If the events under consideration occurred in a totally random, or unstructured manner, there could be no way in which the animal could learn to relate its own behavior to the variations in its environment.

For the moment, and assuming a well-established discriminative operant, it is of some interest to examine the structural relation between the animal's acts and its environment. Imagine the trained animal to be placed in the experimental situation with the bar in the "up" position and the light "on." Under these conditions the animal is observed to approach the bar and press it to its "down" position, whereupon the remainder of the familiar sequence of behaviors occurs. Since the behavior of pressing the bar is under the control of the light and the delivery of food is contingent upon pressing the bar, the animal's act is clearly instrumental. Under these conditions it is quite appropriate to refer to the light as a prescriptive sign. However, and as we noted earlier, the animal has acted on the environment (hence the term operant in Skinner's descriptive language) which yields a change in the environment's properties. The bar is now in the other of its two states ("down") and the animal's relation to the environment is that required to achieve this new condition. The "down" position of the bar may be regarded as an emergent sign designating the presence of a pellet of food in the delivery tray, and since the associated act of consuming the food is known to be reinforcing, the sign is appraisive. In other words, appraisive signs are stimuli which constitute occasions upon which the animal engages in other acts known to be reinforcing. It would need to be shown, of course, that the reinforcing act is under the control of the new position of the bar (or the act that yields this state), and this would require the food-deprived animal to engage in the reinforcing behavior only upon the occasions of the lever moving to the down position or upon engaging in the act of pressing the bar to this position. That such a series of events could (in principle) be demonstrated seems to be relatively unproblematic.

The next step in the analysis follows the animal to the tray where the food-pellet is consumed. Again we observe a change in the environment as a consequence of the animal's behavior; the pellet has disappeared from the tray. The empty tray (or the act together with the change it brings about in the environment) may then function as a designative sign having the light as referent. If we assume that the bar remains in the down position until some brief interval of time elapses following the consumption of the food, we may observe the animal to "attend" to the light and, upon its change from the "off" to the "on" state, once again approach the bar and repeat the sequence. The process will presumably continue until the deprivation state is appropriately modified. We would want to be assured, of course, that the empty tray (or the act together with the state of the tray) is the occasion upon which the animal attends to the light - responds "as if" it had the property of turning on after being off. The possibility of arranging conditions to demonstrate that the act of attending to the light occurs only when the tray is empty (or emptied by the animal's act of eating) would be required and, in principle, this appears to pose no serious problem.

The foregoing discussion has been undertaken partly to demonstrate the plausibility of Morris's contention that semiotic is subject to a strictly behavioral account. That is, the notion of sign need not refer to private, internal events which must remain in the realm of unverifiable inference, or for which the only evidence one can find is the "report" of an interpreter. Indeed, the term "sign" need not be used in the analysis. We might have referred only to the stimuli which control behavior in the special context of the discriminative operant. The analysis in terms of designative, prescriptive and appraisive signs (stimuli) mainly serves to identify several important classes of behavior and the effects of reinforcement in a situation requiring adaptation. The special utility of Morris's tri-dimensional theory of signification will be more apparent in subsequent discussions of human communication, in which the signs involved may take a variety of forms which differ in important ways from those functioning in the animal's situation.

The discussion is also presented for the purpose of examining another of Morris's contentions - any discriminable event can function as a sign. If the analysis holds up for events that are usually thought of as nonlinguistic, or non-verbal, and if it can also be shown that a semiotic analysis can be undertaken in purely observational terms, then the analytic framework may prove useful in an objective treatment of "linguistic signs" and their role in human communication. To this end, we next turn attention to a somewhat more detailed consideration of structure and its role in the semiotic, or sign process.

Structure and the Nature of Representation

In the discussion thus far, the terms designative, prescriptive and appraisive have been treated as a part of an observer's language. They are proposed to designate a situation in which some constraint exists or evolves between an organism's behavior and certain structural characteristics of the environment. For an observer to learn, for example, that the light is functioning semiotically for the animal, the light must be treated as a variable with which certain behavioral properties of the animal may then be related. If the light is always present and in a single state, it obviously would not be possible for the light to achieve control over the animal's behavior, i.e., exercise a selective function. The same structural prerequisite holds with respect to the matter of an observer's learning about the animal's learning. Again, the light must function as a variable in some sense, and its variation must be related to some variation in the animal's behavior such as pressing or not pressing the bar. Under these conditions (as a minimum), an observer may correctly decide that the light is functioning as a discriminative stimulus with respect to the operant described as bar-pressing, or, in other words, that the light is functioning as a prescriptive sign.

If the foregoing account is correct, then it seems plausible to regard structure as a necessary condition for any event to acquire "sign-significance" for an organism, and for an observer to learn that this has occurred. We need next, then, to examine the concept of structure in somewhat greater detail.

In Polanyi's view of the problem-solving process, the problem-solver is seen as routinely engaged in an effort to "...retain control of itself and its surroundings." As we have seen, however, at least in the operant learning situation, there is an additional condition of control to be considered. The experimenter has pre-controlled the animal's environment, thereby establishing a condition essential for the animal's learning (adaptation). To say that the environment is "under control" is to say at least that the objects and events which make up the environment are constrained in some manner; that fewer things or combinations of things actually occur than could occur. Thus, for an observer of a situation which includes a man walking his dog, the spatial relations involved are constrained or limited by the leash connecting man and dog. The conditions which are said to be responsible for the constrained relation need not be physical of course. The relation between the man and his dog is also constrained when the dog obeys the command to "sit." Similarly, when the animal in the experimental situation learns to "obey" the light by pressing the bar, a condition of constraint characterizes the relation between the animal's behavior and the states of the light.

Thus far in our discussion, we have assumed the environment to have been constrained in some manner before the animal arrives on the scene. The animal's task is then to accommodate its behavior to the existing structure if its "problem" is to be solved. In this context we are assuming the animal's problem to be alleviating the condition implied by the phrase "food-deprivation." We are not concerned at the moment with the question of who or what may be doing the controlling, but we are concerned with the conditions which are necessary for any situation to be described as "under control."

The foregoing examples suggest that in the simplest of cases control may be treated as a two-term relation in which one object or event is said to be under control with respect to some other object or event when the states of the first are correlated with the states of the second. Thus, each of the objects or events must be capable of assuming more than a single state - _structure requires variability_, i.e., there must be at least two elements and the elements in question must be capable of assuming more than a single state.

A particularly useful way of viewing this matter has been presented in detail by Garner, and his discussion of _contingent uncertainty_ is relevant to the conceptual position developed in this discussion. (Garner, 1962)

Garner's treatment of uncertainty in the univariate case is based on the familiar treatment of information as the logarithm (base 2) of the number of alternative values of some variable. When the probabilities of the several values are not equal, the well-known Shannon measure of average information is employed with the exception that it is treated as a measure of average _uncertainty_:

$U(x) = -p(x)\log p(x)$ (Garner, 1962, p. 21)

A similar measure is employed in dealing with the uncertainty of the bivariate case in which the measure is applied to the matrix composed of the probabilities of joint occurrence of the values of two variables:

$U(x,y) = -p(x,y)\log p(x,y)$ (Garner, 1962, p. 54)

which provides a measure of the actual joint uncertainty for a particular matrix. If the two variables are orthogonal, then the actual uncertainty will be equal to the maximum uncertainty which could occur and this, in turn, is equal to the sum of the uncertainty measures for each of the variables considered alone. However, if there is some degree of correlation between the two variables, the actual uncertainty will be less than the maximum uncertainty. The difference between the values defines contingent uncertainty in the bivariate case. Thus:

$U(x{:}y) = U_{max}(x,y) - U(x,y)$ where

$U(x{:}y)$ is a measure of contingent uncertainty,

$U_{max}(x,y)$ is a measure of maximum joint uncertainty and $U(x,y)$ is a measure of actual joint uncertainty. (Garner, 1962, p. 56)

Contingent uncertainty measures the amount of reduction in uncertainty due to the correlation between the variables. Another way of viewing contingent uncertainty is to think of the variables x and y as "input" and "output" signals and contingent uncertainty as transmitted information. The performance of the system may then be represented as a joint probability matrix from which the amount of transmitted information may be calculated as contingent uncertainty. The concept of transmitted information may be construed as the discriminating ability of a human being if the joint probability matrix is constructed in terms of stimuli as one variable and responses as the other(Garner,1962,p.54-63).Similarly, transmitted information may be construed as the amount of structure, or control characterizing a system of signs as inputs and operants as outputs. In general terms, then, we may think of structure as the amount of correlation between specified sets of events for which contingent uncertainty provides a suitable measure in informational terms.[1]

In the preceding discussion, uncertainty does not, of course, refer to an internal state or feeling of an individual. The several forms of uncertainty can be employed, however, in describing the relations between the animal's behavior and the characteristics of its environment. Similarly, the behavior of an observer of the animal and its environment may be treated in these terms. Consider, for example, the situation in which a fresh animal (food-deprived and untrained) is placed in the experimental space as it was described in the earlier discussion concerning signs. We would expect certain behaviors of the experimenter to be correlated with the behavior of the animal as well as with the structural characteristics of the animal's environment. Presumably, (and under certain conditions), he would "record" the states of the light, the bar-pressing of the animal, the instances of eating behavior and so on. The product of such behavior (e.g., tally marks in discriminably different places on a sheet of paper, etc.) would ordinarily be thought of as a *representation* of the animal's behavior in relation to its environment. Now, if the experimenter's representation is assumed to be the output of an error-free transmission system, and if, in turn, the representation is characterized by some amount of contingent uncertainty, then to that extent, the variables involved *constitute representations of each other*. In this sense of the term, the light *represents* the behavior of the animal in pressing the bar just as the behavior of the experimenter represents either or both of these events. This development of the concept of representation is derived in part from the suggestions of MacKay. To elaborate the notion, consider a simple mechanical system. Such a system is designed to perform within its field of activity as if it "knew" the state of affairs within that field. Thus, a thermostatically controlled heating system "acts as if it knows" what the temperature is. Although this may require that information about the state of the field have some physical representation within the mechanism, by representation we can mean any set of objects or events exhibiting in at least one respect (even if only statistically) the pattern of relationships between the components of the field of activity. Thus, the pattern of impulses transmitted by a thermocouple constitutes a representation of the temperature variations in a room. Or think of a man driving down a road at a constant speed. The sequence of movements of his arms may be said to form a representation of the geometrical aspect of the road (MacKay, 1956). From that sequence of movements an observer could construct a map (another representation) of the road.

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[1] Garner extends the analysis to "multivariate information transmission" employing essentially the same approach as in the bivariate case. The reader is referred to this work for the more detailed considerations. For present purposes, the bivariate analysis is sufficient to establish a working basis for the discussion of structure.

Still following MacKay, we can amplify the illustration by imagining a car guided along a road made up of straight stretches and right angle turns, by means of a pair of buttons causing the car to turn right or left. Again, the sequence of L and R button pressings would form a running representation of the road. Obviously, if the shape of the road is completely irregular, then no sequence of L's and R's is more probable than any other, and the driver must be equally ready at all times to turn left or right. Suppose, however, that the shape of the road is regular, that it consists of the sequence LRLRLR----. Under these conditions the sequence of turns is internally structured and the driver who has learned this to be the case can also learn to "anticipate" each turn in the sequence. He can then be ready to turn R after L or L after R. We may also note, according to Morris's treatment of designative signs, the sign event is said to mediate an interpreter's expectation with respect to something else. Thus, for the driver, a left turn in the road may serve as a designative sign with respect to succeeding portions of the road; and for an observer of the driver's behavior, each control act may serve as a designative sign either with respect to the next act in the sequence or with respect to characteristics of the road itself.(Morris, 1964). In other words, when one learns the structural relations which characterize the environment, one of the essential conditions has been met for structuring (or controlling) one's relation to that environment, and this would appear to involve "predicting," "anticipating," or "expecting" one thing on the basis of another.

From one point of view it seems quite plausible to suggest that "knowing" and "anticipating" can occur only if further requirement is met; i.e., the driver must be capable of storing internally a representation of the turns in the road. For those whose theoretical interests involve constructing machines to duplicate the driver's performance, describing the details of an appropriate "storage" and "retrieval" operation obviously is essential. However, for the present, we will continue to assume the position of an observer and what is immediately available for observation is the driver, variations in his behavior and variations in the road. Over time, and assuming favorable observation conditions, a particular driver's behavior may thus acquire considerable stability in the sense that any tendency to turn left when a right turn is next in the sequence is reduced to, or nearly to, zero. If the driver has not "learned" the road, or if the road consisted of random turns (in the extreme), the driver can only "feel" his way cautiously under the correction of immediate sensory indication of momentary deviations from the correct position on the road. In this simple illustration, what can be observed are the turns and the structure characterizing the turns on the one hand, and variations in the behavior of the driver on the other. The degree to which the relation between these events is "under control" or structured is a measure of the representational capacity of the relation, i.e., the capacity of the driver's behavior to represent the sequence of turns in the road, or the reverse.

Thus, for one set of events to serve as a representation of another, there must be a structural relation holding between the sets in question. A representation requires, therefore, a state of *related uncertainty*, and as Garner has suggested:

> The reason for making a special point of this relation is that it has so frequently been misunderstood when we apply the concept of structure. It sounds reasonable to say that structure is the lack of uncertainty, but the statement is wrong. Structure is *related* uncertainty, not the lack of it, and to have structure is to have uncertainty. (Garner, 1962, p. 339)

The reason for making a special point of the matter in the present discussion is simply that some amount of structure in the sense of related uncertainty is not only essential if the driver's behavior to represent the road, it also appears to be an essential pre-condition for the process referred to by Morris as semiosis.

Returning once again to the hungry animal, its behavior over time may be said to represent the structure of its situation. We do not mean to say that the animal has acquired a representation, nor do we mean to say that a representation is "in the head" of the animal's observer. Rather a representation is a form of observable behavior which has a structural relation to something else. By this treatment, the animal's behavior represents the structure of its situation (given time and the conditions required to establish the discriminative operant), just as the behavior of an observer may represent the structure of the animal's environment, the animal's behavior, and the relation between them. Representations thus emerge as hierarchical structures and it is well to keep as clear as possible about the levels of representation which may be involved in the analysis of semiotic behavior and, ultimately the analysis of communication.

We have already noted that by Morris's treatment, the significations of signs are objects or their properties which are *not at the moment acting as a stimulus*; and in the case of the driver referred to earlier, a left-hand turn in the road may serve as a sign designating a *yet unobserved* right-hand turn. Similarly, for the animal in the experimental situation, the light is a sign with respect to the bar as signification. A critical property of semiotic behavior, then, is that it involves a response to something else and at a time subsequent to the occurrence of the sign. In this sense, signs mediate *future* behaviors on the part of the interpreter, but this is not necessarily to say that signs mediate the interpreter's expectation if this term is taken to refer to some internal cognition. Simply because the animal behaves toward the bar in a particular way on the presence of the light, or the driver behaves toward the next turn in the road in a particular way on the presence of the present turn, is not sufficient evidence to conclude that either of them expects certain things to occur. The term "expect" or "anticipate" may be used, however, in the description of another's behavior when reference is to a condition in which there is some temporal delay between sign and interpretant during which certain intervening behaviors may occur such as: (1) conditioned reflexes involving factors such as respiration, pulse, etc.; (2) close attention to stimuli intervening between sign and the interpretant; (3) behaviors typically associated with the occurrence of either positive reinforcement ("joy") or negative reinforcement ("anxiety"); and

(4) behavior which makes the interpretant more effective (e.g., postural adjustments) or even partial executions of the more complex act which is taken as the interpretant. (Skinner, 1953, pp. 125-128)

Following these suggestions, the term expectation may be used to refer to those behaviors which serve as reliable designative signs for the observer which have the interpretant of the observed organism as a referent. An alternative use of the term rests on a distinction between an organism's "predictive" behavior in a given instance and the statistical characteristics of this behavior over a sequence of similar instances. It is this alternative to which attention is turned in the following section. The proposal is more nearly descriptive of the organism's behavior.

Prediction and Expectation

Still another approach to the treatment of expectation as a term in an observer's language may be explicated with reference to the operations typically employed in experimental investigations of probability learning. We will consider particularly operations similar to those used by Siegel in his studies of decision-making and the influence of certain "utility" parameters. (Siegel, 1964)

Briefly, a person is shown a small light and told that it may be in one of two states, on or off. He is then shown a small window and told that when the light (the "warning" light) is on one of two events will follow in the window - a red light will come on or a green light will come on. He is also told that the warning light will turn on and off in a regular temporal sequence. The person's task is to state which of the two events (red or green) he believes will occur in the window each time the warning light turns on, and then to observe which of these events actually occur. Let us ignore, for the present, the fact that the experimenter and his subject have "communicated" and assume that the subject "understands" the situation and his task. This is tantamount to the assumption, in principle, that the subject could learn to engage in some act, say pressing a key, that either "matches" or does not "match" the subsequent state of the window. Presumably, this may be accomplished through an appropriate structuring of the situation together with suitable reinforcement. If these assumptions are correct, the fact that the subject was brought to this behavioral state through other means is incidental in the present context. (It is decidedly not incidental in the context of interpersonal communication, however; and as later discussion is intended to show, a complete analysis of communication requires both processes to be taken into consideration.)

We will further assume that the experimenter has arranged the sequence of red and green events such that the probability of the red light following the warning light is .90, while the probability of the green light following the warning light is .10. The sequence is otherwise random. We may then regard the warning light as a designative sign insofar as it signifies a change from the "off" state of the window (say a neutral grey) to either red or green. To this extent, it functions in a highly reliable fashion. However, when the warning light is on, either of two conditions can occur in the window, red or green. Thus, the instructions (or the equivalent learning experience) limits the subject's uncertainty since only two alternative states are associated with the "on" condition of the light. Since both the subject and the experimenter know this to be so, it seems reasonable to say that the "subjective" and the "objective" uncertainties are matched in the amount of one bit. Alternatively, we may speak of the "surprisal" of the red and green events, and in view of the differential probabilities of occurrence (.90 and .10), a fact known only to the experimenter, the surprisal values for the two individuals are not the same, and our problem is to estimate this value for the subject.

For the experimenter, the surprisal associated with red or green is a function of the known probabilities and for red is .15 bits. Similarly, the surprisal value for the occurrence of green is 3.32 bits.* (Attneave, 1959) As Attneave has pointed out, these measures are reasonably consistent with our more intuitive notions relating "surprise" to the relative frequency of events. In this case, the calculated values appear to apply either to the empirical sequence of red and green events or to the experimenter's knowledge on the assumption that what he "knows" matches these characteristics of the sequence (in the sense described below), but no more.

Can anything be said about the surprisal values for the subject? The answer to this question depends, in part, on how much of the sequence the subject has been allowed to observe. It seems reasonable to assume that at the outset the subject "expects" the two events to occur equally often. In this case, the surprisal values would be one bit for each of the events. The assumption is not necessary, however, for we can examine the sequence of statements (or key-pressings) for the relative frequency of red and green predictions. According to the evidence reported by Siegel, we would find the relative frequencies of such predictions to converge on the known empirical probabilities with increasing exposure to the sequence (Siegel,1964). Thus, we would be able to detect the shift in surprisal values from the initial amount of one bit to the values assumed at the outset for the experimenter. The probabilities used to calculate the surprisals for red and green for the subject are based on a limited sequence of predictions and therefore provide relatively instable estimates. However, if the subject should stabilize at the level of predicting red with a probability of .90 (a situation referred to by Siegel as employing a "matching strategy"), the surprisals for the red and green events match those for the experimenter - the subject has now learned what the experimenter knew at the outset.

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* $h_{red} = \log_2 \frac{1}{P_{red}}$

Let us now assume that the subject is working in a context that provides "pay-off" (reinforcement) for matching his predictions with the actual events trial by trial. There are four possible combinations of prediction and actual state, two ways of getting a match and the two ways of getting a mismatch. That is, we may speak of *confirmed* predictions and *infirmed* predictions and further note (for a stable, matching strategy) that for an incorrect prediction of red, the infirming event has a surprisal of 3.32 bits while for an incorrect prediction of green the infirming event has a surprisal of .15 bits. If we speak of the event itself as informative in the amount of its surprisal value, then we may also speak of the amount of *infirmative* and *confirmative* information associated with each event in the sequence. In addition, for some part of the sequence of predictions prior to stabilization it would seem reasonable to speak of *constructive* information as that which contributes to stabilizing the probability characteristics of the prediction sequence itself. In this case the amount of constructive information would depend on changes in the surprisal values trial block by trial block.

Given this loose description of events, we may then make a distinction between *prediction* and *expectation*. A *prediction* of red is consistent with the *expectation* that red is the more frequent event, but so is a prediction of green since green does occasionally occur. In other words, if we treat the concept of expectation probablistically, then single events are not sufficient to either infirm or confirm expectation. To speak of the subject's expectation in this situation is to speak of the relative frequency with which he predicts certain events. Particular events may function constructively or, they may function to infirm or confirm predictions; but by the present usage, only *sequences* of events may infirm or confirm expectation. Supposing a stable, probability-matching performance on the part of the subject, observations of a sequence of red and green events confirms the expectation that red occurs more frequently than green.

We may also note in passing that the amount of information associated with the confirmation or infirmation of *expectation* may be calculated by the weighted average of surprisals across a sequence of decisions or events. Considering the events, the maximum average information would occur with a random sequence of equiprobable red and green events. The actual information (on the average) associated with the sequence in the illustration is .47 bits[*]; thus, for a subject with an expectation of equal probabilities of occurrence, the average information for the trial block in question is one bit. The difference of .53 bits represents the amount by which the fifty-fifty expectation has been infirmed.

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[*] $H = -\sum^{j} p_j \log p_j$ (Attneave, 1959, p.8)

The analysis thus far treats expectation as a probabilistic concept and prediction as particularistic. In the example chosen the redundancy involved was only first-order, i.e., based on the probability imbalance holding between the occurrences of the red and green events. If redundancy of a higher order had been involved but which also preserved the probabilities in the example, the analysis of information associated with expectation would be altered considerably. Assuming the subject capable of detecting and utilizing the higher-order redundancy in formulating predictions, then his stable-state strategy matching the empirical probabilities would also reduce to zero the amount of infirmative information since there would be no predictive error. The expectation of red occurring more frequently would, of course, be perfectly confirmed. Thus, we may speak of events as information which infirms or confirms (particularistic) predictions or (probabilistic) expectations. Again, prediction and expectation refer to observable properties of behavior and not to internal states of the actor.

Sources of Information

In a brief review of the terminological confusions surrounding the concepts of "information" and "communication" Morris has proposed to "...limit semiotic to processes involving signification and hence interpretants"(Morris, 1964, p. 64). Recalling that an interpretant is "a disposition to react in a certain kind of way because of a sign," and that significations of a sign are the kinds of objects to which the reactions occur, his treatment of information seems reasonable: "to gain information is to have a change in our expectations (our dispositions to respond) caused by a sign." In view of the preceding analysis, however, we may suggest a somewhat altered view; i.e., any event or sequence of events is informative if it causes a change in subsequent predictions or expectations. Signs and representations are events having special significance since they influence predictions or expectations with respect to something other than themselves. Thus, to gain information is to have a change in prediction or expectation which is caused by events as they are perceived directly, or which is caused either by signs or by representations. In general, representations may be regarded as assemblies of signs and significations (in the designative case) which reveal the structural properties of the events which are represented. The representation of structure is a function which signs considered alone cannot perform.

When signs mediate predictions, the predicted event may confirm (or infirm) the prediction in an amount which depends upon the discrepancy between the number of empirical alternatives and the expected probabilities (which are taken as "empirical" and always based on some observer's specification). In the example we have just considered, to say that the actual probabilities are .90 for red and .10 for green is to say that the experimenter has arranged (and represented) them to have these values. Thus, in an amount which is relative to some other observer, a sign may mediate a gain in information if the predicted event confirms the prediction. The sign may mediate a loss in information if the predicted event infirms the prediction.

Presumably, the same analysis holds for expectation in that a representation may mediate a gain in information if the expectation is confirmed by the relevant series of events but a loss if the expectation is infirmed by the events in question. Again, the amount of gain (or loss) can only be calculated relative to the expectation of some other observer.

The foregoing discussion assumes at least two _sources_ of informative events - direct perception of the environment itself and signs or representations which are also environmental events having an additional and unique function. Events of the first kind are involved in the process by which an actor learns to align his predictions, either in a given instance or over time, with the structural properties of empirical events. Achieving the state of alignment requires reducing or eliminating the discrepancy between the informational characteristics of empirical events and those of prediction and expectation. Events of the second kind are also involved in achieving alignment, but they are of the particular kinds we have called signs and representations. Signs and representations, as physical events, may be properties of the actor's physical environment, the behavioral properties of others similar to himself (his social environment) or properties of his own behavior.

If we refer to the first of these alignment processes as _process alpha_ and the second as _process beta_ (which is distinguished from the first by semiotic mediation), communication may be regarded as a form of interaction between the two. _Interpersonal_ communication then identifies a subclass of interactions in which the semiotic behaviors of one individual constitute the signs or representations of process beta as this process may be observed to facilitate, inhibit or leave unaffected the course of process alpha for another. When the signs and representations of the beta process cause a better (or more rapid) alignment in the context of process alpha, the process of communication has a facilitating effect; when the alignment is worsened (or retarded) the process of communication has an inhibiting effect. When the alignment remains unaffected, the process of communication is irrelevant. Facilitation, inhibition and irrelevance are defined, of course, in terms of the informational properties of behavioral events (instances and sequences of predictions) and the corresponding properties of what are taken to be the empirical events in a given situation.

The Construction of Representations

The next point has to do with the conditions which lead to the "construction" of a representation. If a sign is to acquire control over the "selections" made by its interpreter, there must be a set of possible objects (significations) which includes the object signified; and there must also be a set of responses which includes the response to be made (interpretant). When the sign occurs, the interpreter may be thought of as engaging in a "search" for an object and a mode of response to the object upon which the reinforcing events are contingent. As the animal learns to perform the required act, the probability of performing any of the alternative acts is decreased - the search becomes more constrained.

As we have seen, the search may result in a behavioral representation of the relations among the variables of the animal's environment, and the behavior thereby achieves an emergent sign-potential of its own. Another organism can, in principle, learn to respond to the behavior of the first as signs which have objects of the environment as their significations, and which replicate the environment's structure. As Garner has suggested, the search for structure may be inherent in behavior:

> People in any situation will search for meaningful relations between the variables existing in the situation, and if no such relation exists, or can be perceived, considerable discomfort occurs. The search for structure will occur with respect to either internal or external structure, but preferably for both. Thus we will try to perceive the relations which exist in the stimulus environment, but we will also try to relate our own behavior to the variations in the stimulus environment. (Garner, 1962, p. 339)

The search referred to by Garner need not, of course, yield a behavioral representation of the environment. For example, a sign may acquire control over an animal's behavior even though there is no structural relation between the states of the sign-event and the states of other environmental variables. Thus, the light in the first experimental situation may have no relation to the delivery of food in the tray; that is, the food may be delivered whenever the bar is pressed whether the light is on or off. Nevertheless, the animal may learn to press the bar only when the light is on. On the other hand, the light may be so related to the bar that the bar will activate the food delivery mechanism only when the light is on. In either case, the animal would behave as though there was a structural relation between the states of the light and the food-delivering attribute of the bar. Obviously, observation of the animal's behavior alone is not sufficient for an observer to decide that the behavior represents the structural properties of the environment.

However, the important point is that behavioral representations of the environment are quite possible and presumably very common. When the behavior of another constitutes the stimuli which form a representation of environmental events and which achieve control over the behavior toward those events on the part of an associate, the essential elements of "sign-mediated communication" and/or "representation mediated communication" are present. These phrases suggest something of the importance of distinguishing between the roles of signs and symbols in the communicative process. We will return to this point later in the discussion.

When the occurrence of a particular event achieves control over the behavior of its interpreter, we have spoken of the controlling event as a sign, and when the several states of an event are structurally related to the several states of another, we have spoken of the result as a representation. A similar view has been advanced by Werner and Kaplan in which they regard signs and signals as synonyms. Thus, "signs and signals are elicitors (or inhibitors) of action; they lead one to anticipate rather than to represent an event." Symbols, on the other hand, are "...entities which subserve a novel and unique function, the function of representation." (Werner and Kaplan, 1963, p. 14)

In the present discussion we have used the term representation to refer to a situation in which one set of objects or events (or values of a variable) exhibits (or replicates) the relationships holding among the members of some other set. Under these situations, one set of events may be said to symbolize another; symbols therefore represent that which is symbolized. In view of the suggestions made earlier concerning structure as an essential precondition for semiosis, the process in which something functions as a sign, symbols (or representations) display the required structure explicitly. Thus, although symbols may function as signs, signs cannot serve as symbols. For example, a road map may elicit behavior in precisely the semiotic sense proposed by Morris and thus function as a sign. But the same entity may be responded to as a representation of the structural relations holding between certain attributes of the territory such that the internal structure of the map is externally structured with respect to the territory. In effect, and by this analysis, a symbol "summarizes" the structural relations chacracterizing the several states of at least two variables. Although one may respond to such a summary as a sign it is quite impossible to respond to a sign as a symbol since a sign is regarded as a particular value or state of a variable. Just as signs may function designatively, prescriptively or appraisively, we may speak of designative representations, prescriptive representations and appraisive representations.

The discussion to this point has assumed that any event whatever may function as a sign for some interpreter in a given context. For example, taking the position of an observer of the animal referred to earlier, the experimental environment, and the experimenter's behavior in relation to both the animal and its situation, one could, in principle, construct a "higher order" representation of the relations among the several events. If the experimenter were to behave "scientifically" we would expect our representation to include his designative representation of the relations involved in the animal's behavior and the variations in its environment. However, in the course of behaving scientifically, the experimenter's behavior may also be observed to function as signs and/or symbols for someone else with quite different significations. This possibility is presumably the basis of kinesiology which is concerned with the manifold and subtle ways in which behavior other than verbal-linguistic may function semiotically. (Birdwhistell, 1963) By the present analysis, kinesic events as discriminative stimuli, may be either signs or symbols; however, they are not treated as a special class of events which require a different conceptual treatment. Similarly, Hall's discussion of the "silent language" reveals the complex roles of behavioral events when these events function as signs or symbols in a semiotic situation in which the significations are frequently novel and sometimes surprising. (Hall, 1959)

Signs, Representations and Lansigns

In the preceding discussion, we have described how the light may be regarded as a sign for the animal in its situation, and how either the light or the animal's behavior may serve as a sign or symbol for another, assuming the animal has acquired stable operant behavior. We have also suggested how the behavior of the experimenter may be treated as either signs or symbols by another person. Although any discriminable event, behavioral or otherwise, may function semiotically, one class of behaviors having particular significance for the human are referred to by Morris as lansigns. Again following Morris, lansigns may be regarded as a particular subset of behavioral events. In the present discussion, lansigns are regarded to be no less natural or observable than any other class of events; however, they function in a particular way - they have shared significations for a particular set or sub-set of individuals and they are "restricted as to their possible combinations." (Morris, 1964, p. 60) Thus:

> A lansign system may be specified in terms of the syntactical, semantical, and pragmatical rules governing the component signs. The syntactical rules are divided into formation rules (governing the possible sign combinations) and transformation rules (governing the sign combinations which may be derived from other sign combinations). If only the syntactical rules are given, a lansign system is said to be uninterpreted; if semantical rules are given, it is said to be interpreted. (Morris, 1964, p. 61)

Lansigns are, of course, behavioral events such as certain acoustic properties of behavior in the case of speech, the "marks" resulting from action taken on other objects in the case of writing, or kinesic properties of particular kinds in the case of "signing." Common, or shared signification in accordance with semantical rules, and combinations of events according to syntactical rules are the distinguishing characteristics of a lansign system whatever the sign-events (or sign-vehicles) may be.

Although any lansign or combination of lansigns may function as a sign, it is the capacity of lansign combinations to function as representations (symbols) that gives such a system its particular utility. The factor of shared signification is not essential for a lansign representation to be replicated, but it is essential if the representation is to be "decoded" in the same way by the several members of a linguistic community. The restriction of lansign combinations through rules is essential for a representation to be that which is either replicated or decoded. The important point is, of course, that what makes a representation is the structure holding between the internal structure of the representation and the structure of the events signified. Rules governing combinations yield structure which is internal to the lansign system, while an interpreted system involves rules governing external structure (semantic rules).

Garner has discussed the matter of "meaning" in a similar fashion, in his analysis, the term may refer to signification or to structure either of which may be internal or external. Structure, as we have seen, involves correlated events. The correlation may characterize the lansign elements of a system (letters, sounds, words, etc.) which provides internal structure; the correlation may also involve the elements of a lansign system and other events (perhaps the elements of another language) in which case the structure is external. Similarly, the signification of a lansign combination may be another element or combination in the same system, or it may involve events external to (not a part of) the system. (Garner, 1962, pp. 140-145)

Thus, we may regard structure, or contingency, in relations among events as a fundamental pre-condition for semiotic, or sign, behavior. Equally fundamental, however, is the interpreter's ability to "construct" representations of structure, and for humans, to replicate and/or decode those representations. In the present view, lansigns, or language viewed as a system of lansigns, provides both a means for representing and replicating representations of the structure of environmental events, structural relations of actors to the environment, and the consequences of such relations.

The foregoing discussion has to do with the obvious and important differences between the semiotic behavior of the animal in the experimental situation and that of a human observer of the animal's behavior. The food-deprived animal learned to behave semiotically through direct experience with the relations between the light, the bar and the food. Under the same or similar conditions of contingency, an observer may acquire behaviors which constitute higher-order representations of the animal's semiotic behavior. Moreover, the representations may be in the form of lansigns. In brief, the observer may be described as having "constructed" a representation through his efforts to relate his behavior to the structure of (a portion of) his environment. For another observer, the states of the variables which comprise the representation may serve as signs or symbols which have the animal's semiotic behavior as signification. It is this distinction to which MacKay has called attention:

> Representation commonly can originate in two distinct ways. The difference between these is the essence of one of the most important distinctions in information theory, between the theory of communication of the one hand, and what, for want of a better term, we may call the theory of scientific information on the other. Both a communication process and a scientific observation process result in the appearance of a representation in the "representation space" of the receiver or observer. But what distinguished communication, I suggest, is the fact that the representation produced is (or purports to be) a _replica_ of a representation already present to (within the mind of) the sender. Communication is the activity of _replicating representations_. (MacKay, 1951, p. 182)

By this approach, the _products_ of "scientific" observation are representations which are presumably built up over time (or learned) by an observer on the basis of sequential occurrences of particular events - the signs, significations and interpretants referred to by Morris. The essential difference between MacKay's formulation and the present one is quite apparent. We take it for granted that whether a representation occurs in the "mind" of observer, sender or receiver cannot be determined observationally. However, as we have pointed out, the behavior of an observer can provide a representation of the events under observation. Presumably, there is no particular difficulty in accounting for the possibility of such a representation being replicated in the observable behavior of another. The replication of representations in this sense, however, is not sufficient to render a full account of communication, since the replication of a representation appears to be little more than a synonym for "imitation." Surely this is not what Newcomb and others refer to as the process in which one person "informs" another.

In the preceding discussion we have introduced the concepts of structure, signs, lansigns, and representations (symbols). We need now to consider what it is that the animal gains from behaving semiotically. Part of the answer to this question is so obvious that it scarcely requires comment. If there was no structure among environmental events there would be no animal to consider, but given structure, the animal must be capable of relating its behavior to the structure which is present. Lacking a capacity for sign-controlled behavior (learning) Ashby's kitten is likely to be burned each time it encounters the fire. Under these conditions, when the structure of the environment produces no change in the animal's behavior, the only change possible is the final, fatal one.

This is the minimum contribution of structure, however, and we need to consider the utilization of structure through signs as a determinant of the animal's adaptive efficiency. In order to highlight this matter let us return to the example of the driver and the road referred to in connection with the concept of representation. Imagine again a driver proceeding along a road composed of a random sequence of unequally spaced right and left turns. Under these conditions, the best the driver can do is to proceed with extreme care relying on his direct observations of the immediately given states of the road. His performance presumably requires highly concentrated "attention" with little residual energy available for any other activity. On the other hand, when the turns in the road consist of regularly spaced and ordered alternations, corrective action can occur with greater economy of effort. The distance driven "per unit of energy" is presumably increased. The improved efficiency in his performance leaves more energy available for other activities and this may have a distinct adaptive advantage, particularly for complex organisms confronted with a complex, dynamic environment.

The definition of signs proposed by Morris requires the sign's signification to be something which is not at the moment acting as a stimulus. The temporal delay between the presentation of a sign and the response of an interpreter may be highly variable. Moreover, signs may function with high situational specificity (as in the road-driver example) or they may be generalized to sets of similar situations. A given sign-event may also acquire sign-significance in a number of quite dissimilar situations. When the factors of temporal delay generalizability and multi-signification are considered jointly the possibility of increasingly abstract semiotic behavior emerges. A number of authors have called attention to the possibility of error associated with higher orders of abstraction. The treatments proposed by Johnson (1946) and Hayakawa (1964) are well known in this regard.

On the other hand, "abstract" signs and representations allow certain semiotic manipulations to be conducted which provide a distinct advantage for organisms having this capacity. This possibility is more readily apparent when it is recognized that many if not all semiotic acts are acts of measurement. Although this may not be a widely held point of view it is in accord with the treatment of measurement discussed by Stevens (1951) and by Hawkins who includes in measurement "all empirical discrimination." (Hawkins, 1964). Measurement, for Hawkins,

> ...is synonymous with what is ordinarily in science called observation. Any act of classifying a thing by its observable properties or relations is, in this sense, a measurement.... Thus, quite generally, measurement is some procedure of observation, the outcome of which reduces the extension of a set of alternatives. (Hawkins, 1964, pp. 86-87)
>
> From the present point of view the taxonomists' procedure for determining the place of an organism on the kinship map of living things should be regarded as a type of measurement just as quantitative, just as much to be eulogized for the services it performs, as any other type. (Hawkins, 1964, p. 101)

It would take more space than can be afforded here to develop this notion fully, but Bronowski has pin-pointed the basic element in the statement,

> Man's sole means of discovery is to find likenesses between two things. To him, two trees are like two shouts and like two parents, and on this likeness he has built all mathematics. A lizard is like a bat and like a man, and on such likenesses he has built the theory of evolution. (Bronowski, 1955, p. 427-428)

Underlying the likenesses identified by Bronowski, of course, are the perceptions of likeness which lead to the classification of a variety of dissimilar objects as lizards, a number of other very different objects as bats, and still others as men. The objects do not come in identical sets with names attached. The human animal groups together sets of things which are far from identical, and, over time acquires a sign to "stand for" all members of the set. Common-sense and scientific languages record these likenesses and indicate what is entailed by membership in the set. An object reliably classified as metal will not float, will expand if heated, and fall if unsupported, and so on. "Float," "fall," "expand," "heated" are similarly symbols for sets of like events. A fall is a fall whether the object is a stone, a drop of rain, or a tree. Signs and representations seem to be clearly involved in the process.

Classificatory activities proceed in two directions. One is the detection of more inclusive likenesses and the inclusion of greater numbers of objects under a smaller number of more general categories. The other is the detection of differences within likenesses, i.e., of identifying subclasses with classes, or making fine discriminations. One very broad system of classification is that provided by species, genus, family order, class, phylum, and kingdom. Now, Hawkins' point is that there is no fundamental difference between the act of placing a given object in the species homo sapiens on the one hand, and placing a given velocity in the class of 50 mph velocities. Both acts are basically classificatory. Both place an object or event in a class with a set of like objects or events. The nature of calculation that the two instances of classification permit may be very different, but that should not obscure the fundamental similarity of the processes.

To return to the point of relevance for present purposes, the sign, whether linguistic, mathematical, or other, "standing for" a limited number of likenesses across otherwise different concrete objects and events is sufficiently generalized so as to apply to a large number of concrete objects. To signify is to measure; placing two objects under the category "dog" is to give them equal value, and placing one under the category "great dane" and another under the category "chihuahua" is to give them different values. The latter is no different from placing one automobile in the category "$4000," and another in the category "$3500," although the monetary measure permits one to make computations that the other does not, and vice versa. Of course, the fewer likenesses and/or differences signified by a sign, the greater the number of objects included in the set, i.e., the more abstract, the more general.

We pointed out above that sign-mediation yields efficient performance. Efficient performance, in turn, means that in any given setting energy is conserved leaving greater amounts for other activities. Thus, an organism having a number of conditions to meet, whether for survival or learned goals, stands to benefit greatly from sign mediated behavior. If its survival requires food, water, and shelter, and if its food seeking behavior is efficient, then it has more time and energy left to devote to seeking water and shelter. Thus, sign mediation has adaptive significance not only in the sense of avoiding potentially harmful specific acts, and of yielding greater success in relation to specific goals, but also in the sense of providing generalized resources, time, energy, which can be utilized in the pursuit of a variety of goals.

Now, the question is, "What adaptive advantages are provided by symbols (representations) above and beyond those yielded by signs alone?" One advantage is clear. Symbols can be substituted for objects, events, properties and relations, and they can occur, or be produced, independently of the events, etc. for which they are substitutes. When we examine this process more closely we can see that it involves a tremendous gain. To develop and substitute a symbol for an event, object, etc., requires placing that event or object in a class of like events and objects. This, in turn, is an act of discrimination, classification, or measurement. Thus, to discriminate a light, and to further classify its state as on or off, to classify an object as a lever, and its states as up or down, etc. is to engage in measurement. The process is no different from classifying groups into those having three members, those having five members, and so on. To use Morris's terms, signs, significations, and interpretants constitute acts of measurement.

In and of itself, measurement contributes little to anything. But measurement is a necessary prerequisite to calculation, and calculation consists of performing operations on measurements to identify relationships, or structure. The information that one item costs $10.00, another costs $7.00, and I have $13.00, taken alone is useless. But given such operations as add, subtract, multiply, etc., and the relations equal to more than, less than, etc., these measurements can be related to one another in extremely useful ways. Similarly, the information that the light is on, the lever is up, and the food tray is empty, taken alone, is of little use. But add such operations as, "depress the bar," and such relations as, "when the bar is depressed, food is released into the tray," and the result is highly significant. The term "calculation" is commonly reserved for use in conjunction with mathematical operations, but it seems clear that the basic processes are identical. Mathematical symbol systems are highly refined calculation tools. Considerably less refined, but no less mathematical in the present broad sense, is the biologist's taxonomy and evolutionary relations and operations among classes.

This, then, is one powerful advantage. Operations do not have to be acted out. They can be computed with a considerable saving in terms of time and energy, and a considerable reduction of risk. Put another way, the structure of the environment, and between the actor and the environment, can be transferred to, or encoded in, symbols. Certain types of symbol sets may be regarded as coded messages about the environment, which can be decoded through rules to the corresponding objects, events, and their structural properties.

We also need to take into consideration the kind of developments that occur in symbol systems. In order to do so, let us consider a monetary analogy. Barter is the most "primitive" level of economic exchange, and is subject to severe limitations. One can exchange only if he locates a person who has what he wants and wants what he has, i.e., the range of applicability of the item to be bartered is severely restricted. Moreover there are limitations on when the item can be exchanged (since it may deteriorate), limitations of portability, limitations associated with storage, and limitations associated with the settlement of the terms of the exchange. In short, barter is a very cumbersome, awkward, and inefficient mode of exchange. The introduction of a valuable metal as a symbol in economic exchange removes some of these limitations. It widens the range of applicability, removes the risk of deterioration, and increases temporal flexibility. However, it still poses problems of portability and storage, which cannot be overcome short of a meta-symbol which symbolizes, in some degree, the lower-order symbolic metal. That is, the primitive metallic symbolic tends to be replaced in use by paper currency which, to some extent is based on the metal.

A very close parallel can be drawn between the kind of generalization and invention of higher-order symbols in economic exchange and that which occurs in linguistic symbol systems. To provide a simple example one might encode the following messages (partial representations),

1. An object which falls 1 second will traverse 16 feet.
2. " " " " 2 seconds " " 64 "
3. " " " " 3 seconds " " 144 "
4. " " " " 4 " " " 256 "
5. " " " " 5 " " " 400 "

One may then note the extension of range of applicability, and reduction of storage limitations provided by the substitution of the message $S = 16t^2$

for the infinite number of specific messages of which the above are examples.

Exactly the same point can be made in areas in which less rigorous measurements and computations are used. The sentences:

1. Dogs have a spinal column
2. Cats " " " "
3. Horses " " " "
4. Humans " " " "

along with a multitude of others can be replaced by the substitution of "mammals are vertebrates."

The most general outcome of the introduction of symbols, then, is greater efficiency. The same may be said of the introduction of more general symbols, e.g., currency for gold, or $S - 16t^2$ for the specific sentences. In general, we may say that the higher the level of generality of the symbol system, the greater the user's potential efficiency, and the more adequate the user's adaptation.

We need next to consider the connections holding between the process of constructing and replicating representations on the one hand, and the adaptive states of the participants on the other. In other words, we need to examine more closely the essential properties of an adaptive entity and, in that context, the role of signs, symbols and communication. Accordingly, in the next section we turn to a preliminary view of the human being as an adaptive, or goal-attainment system.

The Goal-Directed System

We suggested earlier that interpersonal communication may be regarded as an interaction between two fundamental processes. For lack of better terms we have chosen to call one of these process alpha and the other process beta. Although both processes are variants of learning, we have adopted the present terminology to emphasize the distinction between that form of learning which occurs in direct confrontation with environmental events and another form which is semiotically mediated. As we have tried to show, the two processes are not independent. In process alpha an actor's behavior becomes increasingly structured with respect to the variable properties of its environment. Stimuli emerge as signs and assemblies of stimuli emerge as representations during the course of process alpha. On the other hand, when prefabricated signs and symbols are available they may, under certain conditions, mediate the process of structuring behavioral relation to the environment. The term process beta refers to this possibility. Thus, if we conceive of learning as a process of sequential selections from among the elements in the organism's behavioral repertoire then there are two basic ways in which this occurs, or two kinds of selections. In one case, the environment selects and in the other a communicating organism selects.

However, nothing in the discussion to this point suggests why such structural relations between the behavior of an organism and the properties of its environment are important. That something like process alpha and process beta do occur seems relatively unproblematic; our interest now turns to the question of why they should occur and, in the context of this question, an examination of the idea of a goal-directed system.

In the introductory remarks we briefly considered the plight of the kitten described by Ashby (1960). The likelihood of the kitten becoming a cat depends, in part, on learning how to achieve a particular relation to the fire so as to maintain certain variables within physiological limits. The fire may be thought of as a variable in the kitten's environment having direct and critical significance for the animal's survival; and, in this case, the task for the kitten is to stabilize its physiological condition through adjusting the distance between its position and that of the fire as a function of the fire's heat intensity.

Similarly, the food-deprived animal has the task of learning how to behave with respect to the environment so as to maintain other physiological conditions within certain limits. With respect to our present interests, it seems reasonable to refer to both animals as "having a problem" to solve. We mean to say that for each of them there is a discrepancy between a known present state and another, also known (or knowable), which is essential for the animal's physiological well-being. Alternatively, we may say the kitten's "problem" is to maintain a given temperature level, or the animal's "problem" is to maintain a given metabolic level. Another way of describing this situation is to say that the solution of the "problem" for each requires the "selection" of a response which will produce a particular relation to the environment. However, additional problems may arise if there is nothing to guide the selection, or, once selected, something prevents its occurrence. Skinner writes:

> We face a problem when we cannot emit a response which, because of some current state of deprivation or aversive stimulation, is strong. (Skinner, 1968, p. 132)

This view of the animal's problem may be accommodated to MacKay's conception of "goal-seeking" in the following way. "We may define the statement A seeks the goal X as follows: let the current state of A (plus its environment) be defined as Y. Let X define that state of the A - environment relation which we term the goal of A." Then the statement, "A seeks goal X." implies that A behaves in such a manner as to reduce or eliminate the discrepancy between X and Y (MacKay, "Mindlike Behavior in Artefacts," p. 106). In our terms, A's problem is the discrepancy between X and Y which is resolved through the selection of behavior that will eliminate or reduce the discrepancy.

To remain consistent with our intent to treat the entire process in an observer's language, we will treat the current and goal-states of A descriptively. First, goal-states may refer to conditions which are known observationally to be essential for the animal's biological survival. In the present case it is a matter of observation that prolonged food-deprivation threatens the integrity of the organism and, ultimately, insures its death. Many states, of course, may be characterized as deprivational which have only remote connections with biological survival, and where such connections exist they may be known incompletely, or remain a matter of mere speculation.

In borad terms, and as inquiring observers, we may seek the conditions which are essential for an organism's survival in the physical, social, economic and cultural systems which are relevant to the organism in question.

We may also inquire about such essential conditions as the broader system actually functions, as it is projected to function in the future, or as its members propose that it ought to function. In principle, the search for conditions which are essential for survival, and, in turn, the assessment of a particular entity's adaptive behavior both depend upon which of the foregoing questions is to guide the inquiry. For this and other reasons, the use of survival as the criterion of adaptive behavior requires careful and critical analysis. For present purposes we simply assume that certain variables or conditions can be observationally identified which are essential for the biological, psychological or social well-being of the individual, and that these conditions are finally related to biological survival. In short, we take it as unproblematic that survival is the fundamental criterion against which to assess a system's functioning (Ashby, 1960). However, for most purposes no assumptions need be made. All that is required to identify goals is the observation that whenever the A-environment relation is displaced from a given state there is a tendency to return to that state.

Given an animal with a goal-attainment problem in the sense described above, MacKay has proposed the following basic requirements for successful goal-directed activity: (1) an effector capable of altering the state of Y (the current A-environment relation); (2) the activity of the effector must be controlled by an element capable of receiving information; (3) information as to the magnitude of XY must be fed back from the field of activity to the controlling element there to give rise to activity in (1) leading to the reduction of the discrepancy between X and Y.

In everyday language, there must be a goal, an "ought-to-be." or a preferred state, a description of the actual state, a comparison of the preferred with the actual, action based on the difference between the preferred and the actual, a description of the effects of that action, and so on. There are many familiar examples of devices satisfying these requirements such as the simple thermostatic system in which the effector is a heating unit of some kind and the space XY is a unidimensional temperature scale.

Given a discrepancy between a goal and an actual state of some system, the activity required to reduce or eliminate the difference depends on two fundamental processes - the process of inquiry and the related process of error-control. Returning once more to Morris's tri-dimensional theory of signification, we may identify three related but distinctly different modes of inquiry(Morris,1964,p.27).Thus, designative inquiry concerns properties of the environment as they were, are, or will become. Appraisive inquiry concerns what to prefer, what to want, or what to value. Prescriptive inquiry seeks answers to questions of the form, "what to do?"

If we treat the foregoing questions as problems calling for certain selections (designative, prescriptive and appraisive), then the selections, when compared with actual states, may be in error. That is, there may be a discrepancy between the actual and selected state of the environment (including relations), the actual and selected outcomes of actions performed on the environment, and the actual and selected effects of action on the well-being of the actor. Thus, error-correction is a companion process to inquiry, and both are essential for effective goal-directed behavior. Why this is so becomes more evident when the process of goal-directed behavior is examined in somewhat greater detail.

The goal (MacKay's X) is defined as a relation between the system and its environment. Some object or event, or class of objects or events must be selected as that to which the goal relation is to be achieved; or, to use Morris's phrase, that to which preferential behavior is to be accorded. In short, the system must "know what it wants" and this is the product of appraisive inquiry. The system must have some way of making a choice among the objects with which it is confronted and among possible relations to those objects. Although the choice of the term inquiry may suggest some intra-organismic and therefore unobservable process which guides the system in making its selections, we propose to use the term in another sense. That is, selections are made from known (or knowable) sets of alternatives and they are controlled by (structurally related to) properties of the physical environment, other organisms, or the selecting entity itself. The term inquiry may seem somewhat more appropriate when the human being is the system under observation, particularly when linguistic behavior is involved. Even in this case, however, we are not proposing an intra-organismic referent for the term. Thus, the choice (selection) may or may not be sign-mediated, and insofar as signs are involved, they may or may not be events associated with the behavior of another. In the case of appraisive selections, and speaking in principle, the objects selected, the relation of the system to to the object, the disposition to "protect" the object and/or relation, and the disposition to re-establish the relation when it is disrupted are all subject to observational determination. Moreover, the observer can determine changes in the probability of acts upon which achieving the goal-relation is contingent, and he can determine the "condition" of the system as consequence of such goal-relations. Thus, the food-deprived animal was observed to select certain objects (food pellets) from those available in the environment, to establish a particular relation to those objects (consuming), and to have an altered disposition to engage in certain acts (bar-pressing) upon which the goal-relation was made contingent.

But appraisive inquiry, the selection of goal objects and relations, is obviously not alone sufficient. The system must also be capable of conducting inquiry concerning the environment and its current relation to the environment. That is, the process of designative inquiry is also indispensable to goal attainment. Although this may suggest that the system must have "information" regarding the states of the environment, such as the location of the selected goal-objects, and the system's relation to those objects, we again propose to refer to a process of selection; for example, the location of a goal-object must be selected from a set of alternative locations.

The selections yielded by appraisive and designative inquiry are then employed in performing the essential function described by MacKay as detection, i.e., the system must be capable of detecting the discrepancy between its current relation to the environment and the relation required by the selected goal-state.

To exemplify the function of detection, we may again refer to the experimental animal which is known to have been deprived with respect to food. Food-consumption is also known to be a condition essential for its well-being as well as reinforcing. The X-Y discrepancy is therefore present. When the animal is said to detect the discrepancy, we mean that some form of the animal's behavior is correlated with the presence of the discrepancy. The matter seems to be quite analagous to the problem of signal detection. For an observer to know that another has detected a signal, the other must engage in some form of behavior when the signal is present and not otherwise. In the present case, the "signal" is a known state of the animal (food-deprived). If the animal's behavior is independent of this state, no detection is in evidence. Ordinarily, of course, the acts of the animal which are instrumental in reducing the discrepancy are taken as the correlated behavior to which the term detection refers. Other forms of behavior obviously may come to be correlated with the X-Y discrepancy.

The third form of inquiry concerns the action to be taken relative to the magnitude of the discrepancy between the current and goal-states. The system must now select a particular way of behaving from a set of alternative behaviors and this selection may be thought of as the product of _prescriptive inquiry_. What is observed, of course, is an act (or a sequence of acts) which is instrumental with respect to the discrepancy between the goal and current states of the actor.

Briefly summarizing the discussion thus far, we have attempted to relate MacKay's conception of a goal-attainment (or information processing) system to Morris's tridimensional approach to inquiry. Our interest in the relation is two-fold: (1) to sketch the preliminary outlines of an approach to the human being as an integrated inquiry system, and (2) to propose, within this framework, an approach to the role of signs and symbols, both as they are involved in the process of inquiry and as they constitute the _products_ of inquiry. To put the matter in a slightly different way, the human being may be treated as a system whose survival is dependent upon achieving certain states (goals). When there is a discrepancy between the current state (system-environment relation) and a goal state (required system-environment relation) the system has a _goal-attainment problem_ to be solved. The solution of this problem is dependent upon achieving solutions for three _inquiry problems_, the problems of appraisive inquiry, designative inquiry and prescriptive inquiry. In everyday language inquiry problems are directed by the general question, "What to select?" and a related question, "What are the alternatives?"

If the three problems of inquiry are thought of as problems of selection, then any given selection (designative, prescriptive or appraisive) may be thought of as a tentative solution to the related problem of inquiry. That is, selection implies the possibility of error which is calculated with respect to the discrepancy between the problem-solver's current and goal states. Selections which "don't work" in the service of goal-attainment need to be modified or replaced. Thus, in addition to seeking solutions for the problems of inquiry, the system must also engage in a continuous process of error-control and it will therefore be convenient to speak of the three related problems of control with respect to designative error, prescriptive error and appraisive error. In the case of the error-control problems we conceive of discrepancies between: (1) What is predicted (or expected) with respect to specified properties of the environment (as it was, is or will be) and what is observed to be the case (designative). (2) What is predicted (or expected) as the outcome of action relative to the properties of the environment and the actual outcome (prescriptive). (3) What is predicted (or expected) as the effect on the actor of properties of the environment as they are (or as they become through action) and the actual effect (appraisive).

Thus, given the goal-attainment problem as a discrepancy between the goal and current states, its resolution depends upon designative, prescriptive and appraisive selections which hold error within certain limits. In everyday language, a system must know what it wants, what it has, and if there is a difference, how to act to get what it wants. To the extent that these problems remain unsolved, or inadequately solved, the integrity of the system is in jeopardy.

Viewed in this way, it is at once apparent that unless the system behaves capriciously or randomly, there must be something to guide the selections (predictions and expectations) which constitute tentative solutions for the problems of inquiry; and there must be a capacity to modify such selections when they are in error. As we have seen, there are two fundamental processes by which the problems of selection and error-control may be solved (if they are solved at all). The behavior of the food-deprived animal illustrates, in principle, a situation in which the animal achieved solutions for the three problems of inquiry and error-control in which only process alpha is involved. The power of signs and symbols to influence selections is an emergent phenomenon requiring some form of structure as a pre-condition. This is to say that the light emerged as a sign controlling the animal's selections over time, just as its behavior (as well as the behavior of its observer) acquires a representational capacity over time. Once a sign or representation acquires the power to mediate selections, an essential condition has been established for the problems of inquiry and error-control to be solved through process beta. Thus, when signs and symbols have become the products of process alpha and thereby acquire the potential to influence subsequent selections, the possibility of inter-organismic mediation of problem-solving is established, i.e., the possibility of communication in at least one of its meanings. It will be helpful to treat this matter somewhat more formally.

We have suggested that problems of inquiry require certain selections for their solutions and that what guides the selections are (under certain conditions) signs. This is to say that upon the occurrence of a sign, a particular behavior, or act, is selected; and selection implies a set of alternatives (acts, objects, etc.) from which the selection is made. If we were to adopt the frame of reference of a "communication engineer" we might regard the sign as a "message" which "instructs" the interpreter (or receiver) to select a particular act (or sequence of acts) from an assumed set of alternatives. It is well-known that the amount of information conveyed by such a sign has been defined as the logarithm of the number of alternatives.

In the present analysis, some event (sign) is that which informs an interpreter in an amount related to the number of alternative interpretants which is known to be possible for that interpreter. If there is only one thing an interpreter can do, then a given event assumed to be functioning as a sign can inform him not at all. If, on the other hand, a number of behavioral alternatives could occur then the sign informs the interpreter in an amount logarithmically proportional to the behaviors that could occur. For the animal considered earlier, once the discriminative operant has been established, this means that the "on" state of the light informs the animal in an amount relative to the number of behavioral alternatives which might be observed in that context. If the light comes to control the behavior of an animal for which highly variable behaviors were observed prior to training, then the light informs that animal in some greater amount than would be the case for an animal showing fewer pre-training behavioral alternatives.

This treatment seems quite consistent with what has come to be a "standard" conception of the amount of information in a signal, but it points out the necessity of being clear on how the number of alternatives in a situation is to be determined, or, in other words, whose "uncertainty" is in question. As MacKay has pointed out, "A message provides information only insofar as it reduces uncertainty, and the amount of information is determined by the amount the uncertainty is reduced by the message." (MacKay, "Communication and Meaning: A Functional Approach," p. 172) If it is the uncertainty of the animal's observer with which we are dealing, then the light-animal constitutes the information processing system with respect to which we are inquiring about an observer's uncertainty and his uncertainty involves the number of states of the light, the number of behavioral possibilities for the animal, and the amount of contingent uncertainty which characterizes the relation. If the contingent uncertainty equals the maximum uncertainty, then a ceiling will be imposed on the informational relationship which can occur between these events and the behavior of the observer, which includes the behavior referred to earlier as constructing a representation of the light-animal system. On the other hand, if the light-animal system is not in a state of maximum control, then the "on" state of the light is associated with at least two behavioral possibilities for the animal, and there is, accordingly, some measure of uncertainty characterizing the animal's behavior as it may be represented by its observer.

A similar analysis presumably holds for representations of the structure characterizing the states of two or more variables. The "message" may be signs which select representations, or representations which select representations. In principle, the same information analysis would hold so far as the quantificational characteristics of the process are concerned.

Goal-directed activity as we have characterized it thus far consists in the actor solving certain problems concerning his actual relations to the environment, required relations, differences between the actual and the required, action to reduce the difference and so on through the cycle. If we were to say the actor needs information about the states of the world, himself and his actions, we would be referring (in this context) to the solutions required by these problems. For the present we may treat signs and symbols as messages in the form of instructions to select a particular form of behavior, whatever particular form that behavior may take. This description assumes that goal objects and the designative and prescriptive problems associated with the achievement of a goal state all refer to discrete events in space and time. An alternative, and more inclusive way of referring to the goals of the system and related perceptual and instrumental acts is to consider a sequence of relevant selections over time. When there is some regularity or structure in such a sequence, an observer may then refer to the norms of the problem-solving system. For example, a given food-seeking excursion on the part of an animal may be taken as an instance of goal-directed behavior with a given food object as the goal. But we may also link together the recurring behaviors of this type over time and speak of the general goal-norm of maintaining a given metabolic level. When there is a higher-order structural relation between, say, the problem-solving norms of the system and the survival or demise of the system, the observer may meaningfully report that the system is purposive by which he means that the problem-solving norms of the system are structurally related to the survival of the system.

We need also to extend the conception to include a system capable of representing and comparing representations. That is, given two alternative designative representations of the same situation, two alternative appraisive representations, or two alternative prescriptive represention, the system must be capable of assessing the several representations of each kind and selecting from among them. This higher-order problem of selection involves one or more levels of meta-representations at which representations themselves are designated,appraised and prescribed. We shall refer to these higher-order problems as evaluative problems and the corresponding representations as evaluative representations. Again, evaluative representations may be designative, prescriptive and appraisive. The fundamental process of selection remains unaltered of course. We are merely suggesting that selective acts can occur with respect to objects and relations, representations of objects and relations, representations of these representations and so on. When selections are influenced by signs and symbols a higher-order semiotic process is involved (metasemiotic) which is here called the evaluative problem.

In addition to the normative and evaluative characteristics of a system's behavior, including the behavior involved in constructing representations and meta-representations, we must recognize that designative, appraisive and prescriptive problem-solving whether or not guided by signs or symbols, may have as referent any of an indefinitely large number of objects. We have largely treated the environment of the system as its physical world. Certainly other systems similar to the one which is under observation at a given moment may be the referent for any of these problems as, indeed, may the system itself. Thus, any episode of interpersonal communication may be initiated with respect to, say, objects of the physical environment but quickly display emergent problems with the participants themselves as the referents of the new problems.

A number of authors have modeled human behavior along these general lines, although with somewhat less reticence to construct representations of the internal states of the system than the present authors show. For example, Boulding sees man's behavior as dependent upon his image of the world by which Boulding means an individual's total knowledge. Messages change images, and, thereby a person's behavior. (Boulding, 1956). We have already referred to the view of Geertz concerning the important role played by symbolic events in man's adaptive behavior (Geertz, 1966). As another author has put it,

> Imaginal thinking is neither more nor less than constructing an image of the environment, running the model faster than the environment, and predicting that the environment will behave as the model does. Once a model has been constructed it can be manipulated under various hypothetical conditions and constraints. The organism is then able to observe the outcome of these manipulations, and to project them onto the environment so that prediction is possible."
> (Galanter and Gerstenhaber, 1956, p. 219)

Similarly, Miller, Galanter and Pribram describe the image as including "everything the organism has learned - his values as well as his facts - organized by whatever concepts, images, or relations he has been able to master." For these men plans and images are intimately related, "Changes in Images can be effected only by executing Plans for gathering, storing, or transforming information. Changes in Plans can be effected only by information drawn from Images." (Miller, et.al., 1960, p. 17-18)

Although the terms "image" and "plans" may be taken to refer to internal, private states of the organism, they may also be construed to refer to messages in the form of representations of the environment, action, the outcome of action and so on. In the case of lansign representations having the actor himself as referent, they may purport to have internal states as their referents. The observer may note this to be the case and he may also inquire about the relation between such representations and other observable events, but nothing more. Thus, for example, when another speaks of his states of "satisfaction" or "displeasure," the message, the conditions under which it occurs, and the reinforcing effects of the external events signified (if any) are all subject to observation. Although such an analysis may "miss the point" from the point of view of a subjectivist, such inquiry is clearly not trivial.

Before turning, at last, to a more substantive consideration of interpersonal communication, brief attention must be given to the system's organizational requirement, that is, the process by which the several acts we have separated for analytic purposes are concatenated in accordance with the requirements of goal-attainment. In short, a thermostatically controlled heating system cannot be considered goal-directed if, when the thermostat "reports" a discrepancy, the furnace behaves independently, or capriciously. The results of the system's problem-solving activities must themselves be organized, and this holds whether the system is mechanical or human.

One of the ways the problem has been approached conceives basic behavioral acts as organized by a partially ordered hierarchy of routines and subroutines which embody goals, representations of what is believed to be the case, or a "map of the state of affairs of the world," including prescriptions for how to change that state when it does not match with goals. (These may be thought of as "problem-solving programs.") The total complex of goals and acts may be regarded as a matrix displaying the relative probabilities of various patterns of behavior under all possible conditions.

> ...the internal representation of the world of an organism may be thought of as a statistical /stochastic/ model of the "pattern of demand" made by the world upon the organism. By the 'pattern of demand' I mean not merely those features of the world (such as heat and cold) that bear upon and disturb the equilibrium of the inert organism, but all those that the active organism has to take into account when conducting total directed activity. The suggestion that the organizing system developed to match this pattern of demand (to do the necessary 'taking into account') can itself serve as the internal representation of the world. (MacKay, "Communication and Meaning - A Functional Approach," p. 169)

MacKay appears to refer specifically to what Morris describes as designative inquiry (and we have labeled designative problem-solving) when he writes,

> ...we think of it as the setting up of a hierarchic structure of organizing 'sub-routines' to determine these conditional probabilities, interlocked in such a way as to represent implicitly the structure of the environment (the world of activity) with which the organism must interact. For many purposes we may reduce it to a filling-out of a world map, ready to be consulted according to current needs and goals. (MacKay, "The Informational Analysis of Questions and Commands," p. 470.)

However plausible and useful the foregoing account may be, the "internal representation" of a system's world is not available for the scrutiny of an observer. (As we have repeatedly noted, this comment does not argue against the importance or meaningfulness of such efforts.) The observer can engage in constructing higher order representations of the structional relations holding between the system's designative, appraisive and prescriptive problem-solving activities including the effect of such structural patterns on the system's integrity. Over time, (and in principle) an observer's representations may also include the system's norms, solutions to its evaluative problems and so on. In general, the greater the uncertainty displayed in these representations, the less effective is the system's integration of the basic acts required for goal-attainment, assuming that the source of the uncertainty is not the observer himself.

As we have noted, the observer's representations may include the representations of the system itself. That is, an observer may report how the system is observed to function, but he may also report how the system reports its own functioning. With respect to the later form of representation and specifically with respect to the matter of the system's "internal organization" of basic acts, a system's own representations may be regarded as its plan or prospectus. The system's plan(s) thus include statements of what is, what is wanted and action to reduce the discrepancy. Whether the system's plan "matches" the observer's representation of its functioning and the condition under which it does or does not are questions of considerable practical and theoretical importance.

Returning to the food-deprived animal once again, if the several linkages between the sign-events and modes of response have already been established, there is nothing more to be done but observe the system function as a goal-attainment system. This requires an expenditure of energy to produce the goal-attainment activity but nothing more. On the other hand, if the linkages are not already set up some additional amount of energy must be expended to reduce the uncertainty in the total system of variables.

> ...it is clear that unless the organism happens to be organized exactly to match the current state of affairs, *work* must be done to bring it up to date: not only in a physical sense, but in a *logical* sense. This 'logical work' consists in the adjusting and moulding of the conditional probability structure of the organizing system: the formation, strengthening, or dissolution of functional linkages between various acts or basic sequences of acts. The total configuration of these linkages embodies what we may call the total 'state of readiness' of the organism. Some of them will of course have purely vegetative functions that do not concern us. What does interest us is the total configuration that keeps the organism matched to its field of purposive activity, and so implicitly represents (whether correctly or not) the features of that field. For brevity, let us call this the *orienting* system, and the corresponding total state of readiness the *orientation* of the organism.
>
> Information can now be defined as that which does the logical work on the organism's orientation. ...A solitary organism keeps its orienting system up to date in response to physical *signs* of the environment, received by its sense organs. This adaptive up-dating of the orientation we call *perception*. We can regard communication as an extension of the process whereby some of the organizing work in one organism is attempted by *another organism*. (MacKay, "The Informational Analysis of Questions and Commands," p. 470)

Summarizing the over-all conceptual development to this point in the discussion, we have suggested how *signs* and the semiotic process emerge out of the process by which an organism's behavior comes to display a structural relation to a pre-existing structure holding among the events of its environment. We further identified a distinction among signs (depending upon the significations and interpretants) such that certain events may function as designative signs, prescriptive signs, or appraisive signs. When signs function in a particular situation, they control the organism's behavior. To the extent that such control is actually present, the organism's behavior was then said to represent the structure of its situation.

Similarly, the organism's behavior may serve as signs for some observer, or alternatively, the behavior of an observer may come to represent the relation between the organism's behavior, the structure of its environment or either of these events considered jointly. The behavior of an observer may also constitute signs for another with either the organism or its environment as signification. The distinction between signs and representations turns on the replication of structure in the case of representations.

Lansigns are signs with shared significations, sets of lansigns selected by specified formation rules provides for the possibility of lansign representations, or symbols. Thus, the lexical units and combinations of units which characterize a language (as it is ordinarily regarded) may serve either as signs or symbols.

For a second observer, the behavior of the first observer may therefore function as signs or representations, and if the behavior of the first is in the form of lansigns, there is the additional possibility of either a lansign mediated relationship between the two observers, or a symbol mediated relationship. Either of the observers may be treated as goal-attainment systems for which the solution of the goal-attainment problem depends upon the adequacy of solutions for the problems of designative, appraisive and prescriptive inquiry and error control. Thus, the second observer may construct designative representations of the first observer's problem-solving behavior. Over suitable periods of time, this may include representations of norms, evaluative selections, and effectiveness as a purposive system.

The observational and representational activities may be conducted, of course, with the second observer as the object of reference for the first. However, each may contribute to the construction of representations by the other with respect to each other or with respect to their respective fields of purposive activity. Thus, one observer may come to participate in the problem-solving activity of another, and our task is to specify at least some of the conditions under which inter-participation in purposive activity and the related problem-solving activity may arise. In short, our conceptual interest now turns to interpersonal communication as a process in which the *purposive orientation* of one system is influenced by the semiotic characteristics of another

Interpersonal Communication

Newcomb has conceived communication in terms of the orientation of A to X, B to X, and A and B to each other. Moreover, when A and B have the same orientation to X they are said to be co-oriented. If A and B are each to be regarded as a goal-attainment system in the sense described in earlier sections then each must achieve solutions for their designative, prescriptive and appraisive problems and an organization of solutions that will yield a solution for the higher-order goal-attainment problem. In short, the organism, human in this case, must achieve that designative, prescriptive and appraisive orientation to X, or to each other, which is consistent with reducing the discrepancy between what is and what is preferred, or, in more nearly observational terms, between "what is" and "what is required," either with respect to X or to each other.

Whether the process also yields a state of co-orientation will depend, it seems, on the designative, prescriptive and appraisive states of each actor, and the consequences for goal-attainment of achieving such a state. Furthermore, whether it "ought" to yield such a state can only be judged against the criterion of system integrity and/or survival within for A, B, or X or for the higher-order system of which A, B and X are subsystems.

We have considered at length the process by which the food-deprived animal solved its goal-attainment problem and in which signs achieved control of the animal's behavior. The animal "learned" to behave in selective ways to solve the problem of finding and consuming food. In this case, the signs involved were physical events associated with the animal's environment and the required learning was not mediated by the behavior of another organism. We have also tried to show how the behavior of another organism may (under certain conditions) constitute the signs which achieve control over the selections of the first animal.

There is nothing inherent in the proposal restricting the process to infra-human organisms. But our approach does help to identify a distinction of considerable importance; i.e., as MacKay has pointed out, under certain conditions signs available to the human being may be those produced by another--and the signs in question may also be lansigns, and if so, they may also be *symbols*. Thus, there are two distinguishable processes by which humans may achieve an appropriate orientation to their environment: (1) through learning in direct confrontation with environmental events and the consequences of his own action on those events for the events themselves and for his own well being, and (2) through communication in which the signs available include *lansigns* and symbols (lansign representations). By this treatment, only those organisms *communicate* which are capable of producing or responding to lansigns. (Of course, this is a matter of definition, not of fact.) The reader will recognize the foregoing distinction as the one referred to earlier in terms of process alpha and process beta. That the significance of process beta has been widely recognized need not be documented here.

The purpose of this section is to examine the relation between process alpha and process beta in the context of a functional relation between two individuals when each is regarded as a goal-directed system. In most of our illustrations of goal-directed activity the effector operations performed by the acting system (to reduce discrepancies and bring about goal states) were operations involving the utilization of energy, e.g., producing heat in the thermostatically controlled system. Human effector activity also involves the expenditure of energy, of course, but when the environment includes other humans who participate in a particular lansign system, a new form of effector, or environment manipulating, operation becomes possible. The human animal can act upon his environment not only through the usual processes of expending energy, but through the unique processes involving the production of lansigns and representations; i.e., through communication. *For the human animal, lansign behavior constitutes a highly developed instrument by means of which the environment may be manipulated in the interest of goal-attainment.* Thus, for individual A, another individual B may be an object to be manipulated in the interest of solving A's goal-attainment problem, or any of the subproblems identified earlier. There would seem to be two major avenues through which the former might influence the latter's behavior. First, he may manipulate B's environment so as to arrange events contingent upon B's behavior which are positively or negatively reinforcing to B. Second, he may attempt to bring about a change in B's orientation through the manipulation of signs, lansigns and symbols. Included, of course, are semiotic acts in which the significations are positively or negatively reinforcing events for B.

Returning to Newcomb's conception of communication, and given our view of both A and B as goal-directed, information processing systems, what are the conditions under which A is likely to engage in communication with B, and what is the probable nature of such behavior? It will be apparent that when the states of A, B and X are interdependent a higher-order system emerges which may be decomposed in a variety of ways, depending upon the analytic task at hand. By way of a preliminary analysis, we will refer to two basic forms of an ABX interdependence. First, the ABX system may be thought of as a soliciting system. Consider, for example, the experimental situation described earlier in which an experimenter (A) has structured the experimental space in which the animal has learned to press the bar in response to the light. Another person (B) confronted with X (the animal and experimental arrangements) may query A with respect to X. If the query concerns the relationships between the structure of the animal's environment and the animal's behavior, B's query is designative. B's query is prescriptive if it takes the form of what to do with respect to X, and the query is appraisive if the signs solicited pertain to the reinforcing effects of specified relations to X. In effect, B exposes to A the incompleteness of his own state of readiness. "What is indicated here is the state of readiness of the originator, in relation to the receiver; and this points to a key characteristic of all questions. A question is basically a purported indication of inadequacy in its originator's state of readiness, calculated to elicit some organizing work to remedy the inadequacy." (MacKay, *op. cit.*, p. 472) MacKay has described the "state of readiness" in terms of a simple analogy:

> ...I think the idea of switch-settings in the brain is not a bad way of picturing the mechanisms that embody our "states of readiness." It provides

> us with a useful metaphorical way of looking at a question as an opportunity presented to someone else to set some of the switches for the questioner. It is as if the questioner uncovered and held out the incomplete part of his switchboard to the listener, in the hope of having the switches set for him. (MacKay, "What makes a question?", p. 789-790)

In observational terms, one may treat the concept of readiness as a matrix of conditional probabilities representing the relative frequencies of specified behaviors under a variety of possible conditions. The probability of B querying A with respect to X would vary, presumably, with the values of the appropriate matrix at a particular point in time.

Thus far, we have considered only the subproblems concerned with acquiring a designative, prescriptive or appraisive readiness to act. Solicitation may also occur with respect to the related problems of error control in each of the three domains; and it may occur with respect to the goal-attainment problem itself. In the later case, the query concerns a particular way of behaving to reduce some discrepancy between B's goal state with respect to X and his current state.

Presumably, B might also engage in the process used by A in _constructing_ a representation of the kind sought in his query, that is, he might have engaged in process alpha. If we employ the suggestions of Miller, _et_. _al_., we may speak of B's problem-solving _plan_ in terms of his initiating process beta which generates a communication episode. Alternatively, a different plan is in evidence when B initiates problem-solving activity independently of A, or process alpha. Under certain conditions, the observer may describe the plan selected by B (whether alpha or beta) as heuristic if there is some evidence that it was selected in accordance with a principle akin to "the conservation of energy." That is, if the selection is consistent with B's prediction (which requires an appropriate representation) that process beta will take less time, require less effort, etc., than process alpha. Whether the selection actually confirms his prediction requires some "control data" which is often difficult to acquire, even for the observer. In any case, whether the choice of process beta is a heuristic strategy for acquiring a solution to B's problem would seem to require analysis beyond the act of selection itself.

Several other considerations bear on the functioning of the ABX system as one of solicitation. First, whether B solicits a message from A would seem to depend on the appraisive consequences of such an act for B. Gaining a representation of the kind sought may be a positively reinforcing event, while exposing his "inadequate state of readiness" to A may be aversive. Similarly, for A to supply the solicited representation may have either positive or negative reinforcing effects for him. Presumably, the success with which the communication is carried out (from B's point of view, whether the required representations are forthcoming) depends, in part, on the net balance in the appraisive estimates characterising each of the actors.

Another factor influencing the likelihood of B initiating communication with A as a problem-solving strategy is his estimate of A's credibility. In general terms, credibility refers to B's prediction concerning the facilitative effect of A's reply on his (B's) orientation to X. In terms of the present conception, whether B initiates communication rests on tentative solutions which have been adopted for certain designative problems concerning A as a source of facilitative messages. In effect, this depends on whether A _can_ produce the message sought and, if he can, whether he _will_. The first requires the solution for a designative problem regarding A's designative states, while the second entails solutions for designative problems regarding A's appraisive states. This analysis is partly based on the suggestions of Hovland, _et.al._, who decompose the problem of credibility into two components, the capability of a source to provide valid messages and his motivation to do so. In their view it is useful,

> ...to make a distinction between (1) the extent to which a communicator is perceived to be a source of valid assertions (his "expertness") and (2) the degree of confidence in the communicator's intent to communicate the assertions he considers most valid (his "trustworthiness"). (Hovland, _et.al._, 1965, p.104-105)

Thus, in one of its several meanings, "trustworthiness" involves a solution for certain of B's designative problems with respect to A.

On the other hand, the term trust may refer to the appraisive consequences of "exposing" incomplete readiness on the part of B and the appraisive consequences of replying on the part of A. It will be pointed out later that when communication is chosen as a problem-solving strategy, new problems commonly arise which may involve credibility and trust with yet another meaning. B may attempt to solicit messages regarding A's private states such as his displeasure, anger, sadness, etc., which may be posited by B to be possible characteristics of A. In such cases (whatever B's behavior may imply regarding his conception of man) B is in a position of having to "trust" A to "tell the truth" about states taken by B as unobservables. In this sense of the term trust, and in accordance with the present conceptual treatment, the problem of relating message to event is unsolvable. As we have seen, the term trust refers to several quite different attributes of the A to B relation, and it would appear that some care is required to keep the referents distinct.

The elements A, B and X may function in another way. Under certain conditions A may volunteer designative, prescriptive or appraisive messages in which case B is viewed by A as an instrument to be employed in gaining a solution for his own (A's) goal-attainment problem. This may occur when B's behavior with respect to X has a direct or an indirect effect on the relation A seeks to maintain with respect to X, or it may be the case when the relation between A and B is itself at stake. In either case, B may, by his actions, or failure to act, create a goal-attainment problem for A. Put another way, the maintenance of a given course of action on the part of B may be a goal for A, and any deviation from that course is for A, like a ship's deviation from its course, a discrepancy to be corrected, a discrepancy between an "is" and an "ought-to-be." Thus, A's goal may but need not be a relation between A and B. It may be a relation between B's behavior and some behavioral norm selected by A in the same sense that a helmsman's goal is the maintenance of coincidence between a ship's actual course and one which has been pre-selected. In fact, any condition to be sought, course to be held, state of affairs or relationship to be maintained, may function as a goal so long as deviations from it can be noted, so long as there is a detectable 'mismatch' between an "is" and an "ought."

Given B's deviation from a norm, a course of action preferred by A, A may volunteer a message which has the effect of reducing the deviation. On the assumption that any volunteered message may be regarded as problem-relevant for the individual who does the volunteering, we may refer to this form of semiotic behavior as the production of "instrumental messages." From A's point of view such messages constitute a semiotic form of effector action. It is comparable to the expenditure of energy in any other form in the manipulation of physical or social objects in the service of solving problems. A may seek to establish a norm for B by providing an appropriate appraisive message, and he may further provide both designative and prescriptive messages to signify the conditions which bear upon, and the behavior appropriate to the maintenance of the norm behaviors. In each of these contexts, B may deviate from the signified course of behavior whereupon A would be disposed to provide corrective action in the form of control messages. Again, solutions for the problems of credibility and trust (in any of its several meanings) will influence the communicative relation between A and B. We may note in passing that the possibility of prescriptive and control messages introduces a new form of the trust question - presumably, B will not "obey" control messages from A unless he is assured that the consequences are at least not aversive. If he proceeds only on A's assurances (conditional prescriptive messages), or such messages are not forthcoming from A even though solicited, we would be inclined to say in everyday language that B trusts A to at least some degree.

In the case of solicited signs or representations (from A by B) an appropriate response enables the solicitor to proceed more effectively in the interest of his own goal-attainment. It may be noted, incidentally, that representations may be solicited as a form of control over another's behavior. Thus, a helmsman endeavoring to make good on a northerly course may introduce a correction opposite to one actually required whereupon an observer may respond, (sarcastically) "Does the sun rise in the west?" In this case, the critic is still concerned with the reduction of a discrepancy between the helmsman's performance and a norm although the control message appears to be in the form of a query. In any case, control messages may be either volunteered or solicited, they may be designative, prescriptive or appraisive; and they occur when one person is an "instrument" for the other. Control messages may be differentiated from enabling messages in which the solicitor or volunteer seeks or supplies messages relative to the solution of another's problem. Of course, signs and representations may be provided either voluntarily or in response to a solicitation with indifference to its effect on the other's use of the message; however, there is not indifference to the consequences of responding semiotically. For example, "consultants" may be employed for the purpose of providing either enabling or controlling messages and are sometimes induced to do so through a promise of reward in the form of an appropriate fee. Thus, a consultant may respond to a request for a control message with a conditional prescription ("If you want to achieve Y, do X.") or even a command ("Do X.") and remain indifferent to the behavior of the solicitor in decoding his message. In other words, the nature of the problem guiding the solicitation may be a matter of indifference to the consultant (although it need not be, of course), while the "reward" for supplying a particular message is clearly not a matter of indifference. (This particular form of indifference may and probably does constitute a threat to the survival of the consultant as a particular kind of goal-attainment system.)

In the general case, we would expect A to solicit particular kinds of messages from another depending upon the nature of the problems faced by A and the particular events with respect to which the problems exist. Thus, if A is confronted with a goal-attainment problem defined as a discrepancy between a given environmental condition and A's "preferences" (object values in Morris's terminology, Morris, 1964, p.20), A may solicit a prescriptive message from B. On the other hand, A may be uncertain about whether he actually faces such a problem and may therefore solicit either a designative message or an appraisive message as a "diagnostic strategy." In such a case, A, of course, would have adopted process beta as his basic problem-solving strategy. Depending upon the outcome of this strategy, A may then move to implementing the prescription provided by B.

If the plan (prescription) calls for action which involves the instrumental use of another social object (which may include B himself), A has a new set of problems to solve. First, he must secure the participation of the other (say B) and this involves volunteering appraisive messages to B, perhaps as a part of a conditional prescriptive message, "If you will do so and so then I will do such and such which you will find good." If B agrees to A's proposal (provides a subscriptive reply) then A may also volunteer enabling messages in the form of designative and prescriptive signs and/or representations. Finally, as A monitors B's behavior, he may volunteer control messages when there is some deviation from the course of behavior called for in the initial prescription.

Once B has subscribed to participating instrumentally in A's plan, he may also solicit various messages from A, including control messages. This sequence of events may occur, of course, whether or not it was preceded by the initial consultation. The essential distinction to be made is between a consultative semiotic relation between A and B in which the exchange is potentially enabling for A, and another form of relation in which the semiotic exchange is given to securing a form of behavior on the part of another which is instrumental to A's problem-solving. In a very approximate way, the more usual distinctions between "informative" and "persuasive" communication is caught up in this description.

A similar analysis holds for those problems in which certain properties of A (including his behavior) are discrepant with respect to A's preferences for those properties. Again, A may solicit messages from B (designative, prescriptive and appraisive) which are relevant to the reduction of a specified discrepancy, or he may enlist B as a social instrument to be employed in solving his (A's) goal-attainment problem with respect to his own attributes. The physician-patient relation, psychotherapy and counseling exemplify such semiotic interactions.

Although the analogues of consultative and instrumental interactions may be displayed in simple mechanical systems, there are, once again, important differences between such mechanical cybernetic hierarchies and those in which interpersonal communication is involved. In either case we may view the messages (signals, etc.) as performing a selective function on another component's possible states of readiness. For example, A may "inform" B of the structural relation between, say, two environmental variables (e.g., the relation between the light and pressing the lever in the animal learning situation) whereupon B is "set" or "ready" to perceive the signified change in the animal's behavior upon the appearance of the light, and the actual events confirm the "readiness." In a well-formed cybernetic hierarchy, there is little uncertainty concerning the effect of the message - when the thermocouple signals "heat" the furnace heats. Linkages between human organisms necessarily fall short of the well-formed cybernetic hierarchy, nevertheless, it is clear that a distinction must be made between hierarchical and non-hierarchical linkages.

One of the most characteristic and widely noted sources of error in human cybernetic hierarchies concerns group and individual differences in semiotic performance. One way of viewing this matter has been discussed recently by Brown in connection with the concept of codability (Brown, 1956). The codability of an object or event is seen as related to the lexical resources of a particular community. Brown also suggests the possibility of categorical differences in codability as well as individual differences in encoding and decoding abilities. Considered together as coding ability,

> It is necessary to be able to make an informational analysis of the array of referents so as to identify the distinctive properties of the one to be transmitted.

> It is necessary to control a lexicon and also the grammar of the language. But something else is needed. The encoder must realistically assess the informational requirements of his decoder. (Brown, 1956, p. 340)

Presumably, the factors of codability and coding ability play important but discriminably different roles in human communication systems depending upon the nature of the problems under consideration as well as the nature of the cybernetic linkage itself.

Miller has called attention to another factor which may militate against human systems functioning as well-orded hierarchies, "information overload." (Miller, "Information Input Overload and Psychopathology," 1960.) When a message "overloads" the decoder, a number of adaptive events may occur which are sources of potential disorder with respect to the goal-attainment system under consideration. Similarly, a large number of sensori-motor impairments have been identified which often and sometimes seriously interfere with the encoding and decoding process. Thus, fluency disorders may influence decoding oral signs and symbols through interferences with an optimal rate of message processing, or through evoking irrelevant appraisive problems for the decoder.

Yet another matter influencing the effectiveness of human systems is the complexity of the physical and social environment in which adaptive behavior is embedded. Among other things, it is apparent that human survival requires an ensemble or repertoire of readiness states far exceeding that of a furnace, thermocouple or other mechanical device. Second, and as we have pointed out, the human being may be regarded as a goal-directed information-processing system in its own right, which involves goal-setting not only for itself, but also for the higher-order system of which it is a part, and with its own representations of the common field of activity. No matter how "rigidly" behaviors may be prescribed, there is no way of preventing the several human participants from receiving messages from and having effects on the field of activity. Consequently, the semiotic traffic in signs and representations from organism to organism is far more complicated and unpredictable than the equivalent traffic from mechanical device to mechanical device. Complexity alone, however, would not seem sufficient grounds for invalidating the conceptual views presented in the foregoing discussion.

In earlier sections we have spoken of several types of problems, *viz*., designative, prescriptive, appraisive, evaluative and goal-attainment, etc., all of which involve the reduction of discrepancies of some kind. From the foregoing it appears that the several problems may be subsumed under two higher-order classes of problems. On the one hand there are the problems of *prediction* in which the system is in a state of uncertainty with respect to what was, is or will be; what ought to be, or how to get from what is to what ought to be. This is to say that there are several alternatives from which to select but no basis for making the selection other than a random process. On the other hand, there are those problems in which what is at stake is not predictability, but correction. We may also speak of correction in terms of discrepancy. In the former case, the discrepancy to be reduced is between an actual and a preferred state of predictability; while in the latter case the discrepancy is between the actual state of affairs in the external world and the preferred state. We shall term the first type "learning problems" and the second type "action problems." The first involves identifying structure; the second involves interacting with structure.

As an aside, we may note that there appears to be a relation between these two higher-order classes of problems and the nature of the linkage between two or more information processing systems. That is to say, a well-formed cybernetic hierarchy would seem to eliminate any possibility of learning on the parts of the subordinate elements in the hierarchy since there is no uncertainty characterizing the relationships involved. Obviously, one of the principle conditions leading to the formation of interpersonal semiotic linkages is the absence of a well-formed hierarchy in which identifying structure, or learning is of paramount significance for two or more persons. In effect, when a message is solicited by A and B is unable to respond, the conditions are present for joint inquiry, or collaberative problem-solving, in which learning is the most salient attribute.

Collaberative Systems

With the exception of the foregoing brief comments on well-formed cybernetic hierarchies, we have regarded A and B as relatively independent information-processing systems which interact to provide both enabling and controlling messages for the other. We need now to look more closely at a process which we will call co-action. Clearly, when two human beings are in either face to face or semiotically mediated confrontation, the behavior of each, as we have seen, becomes potential data for the construction of representations concerning both the external events X, the relation of each to the other, and the relations of each to X. Moreover, if the confrontation extends through a sufficient length of time, each individual can form a representation of the semiotic behavior of the other (MacKay, "The Mechanization of Normative Behavior," p. 233). This means, among other things, that each may learn and appraise the goal-setting behavior of the other and adopt the higher-order goal of either maintaining or achieving appraisive co-orientation. In general, securing the benefits of co-action and avoiding the costs of goal-conflict may be thought of as the consequences of such behavior which, under certain conditions, serves to reinforce the emergence of joint goal-setting. Thus,

> Human dialogue can be thought of as a device evolved to this end, whereby not only the indicative organizing system [designative representation] but also the normative metaorganizing system [goal-hierarchy] of each become targets or fields of action vulnerable to "address" by the other -- a special skill, of which language is the typical (though not the only) form. (*Ibid.*, p. 234.)

In the earlier analysis, we viewed, in effect, A and B's goals and goal hierarchy as closed to address, or at least closed to the possibility of reciprocal adjustment. So long as this is the case, A and B may each be regarded as a manipulable system, and each may be regarded as selecting the form of address best suited to accomplishing his ends. Another possibility, of course, is that in which the goals of both A and B are held invulnerable to address. MacKay has likened this situation to one in which two air conditioners with incompatible settings (one heating, one cooling) are operating in a common area. So long as the two remain operative in the common situation, each will operate in continuous conflict with the other (MacKay, "Communication and Meaning," p. 175). One machine could, of course, be provided with means of destroying the other, a not infrequent occurrence in human affairs.

> Suppose, however, that by chance or design, the physical activity of one (or both) succeeds in altering the goal-setting of the other. Displaced in one direction of course would make matters worse; but if instead the displacement brought the two goal-settings _together_, then we would have the beginnings of a wholly different kind of "resolution." Instead of being rivals, the two systems could eventually become _partners_, sharing the effort of furthering the common goal. The closer the approximation of their respective settings, the greater the economy of total effort. (_Ibid_., p. 175)

It is apparent that the case in which the goal-settings of one system are inviolate and those of the other are not is similar to the cybernetic hierarchy discussed earlier. If, however, there are limits beyond which the "open" system will not change, conflict arises again. The only alternative compatible with survival, beyond physical separation, is for the two systems to become open to goal adjustment. Then,

> Each can pursue its goals only by taking into account the goals of the other, not only as facts about the world, but as potential members of its own goal hierarchy. To the extent that B's goal-directed activity can alter the goals of A, and vice versa, it may become impossible to attribute a certain goal to A or B alone. The social unit formed of A + B - in - interaction becomes a goal-seeking system in its own right. (MacKay,"Communication and Meaning," p. 176)

Once certain basic goal-settings have been approximated, and "socialized" goal-directed activity has commenced, each will accord positive preferential behavior (positively reinforce) to anything that brings the organizing system of the other up to date, that improves the match to the current state of the field of activity. This is to say, each will be reinforced by such events. One of the goals for each will be to share designative representations with the other for the purpose of bringing their respective "maps" into coincidence. Another will be to share prescriptive representations, the alternative tricks and skills which may yield the required reduction between the "socialized is" and the "socialized ought." This also requires the development of similar organizing subroutines in the two goal-complexes. Such subroutines may organize the action to be taken (the effector component) or they may concern the process of selecting the action to be taken in view of what is to be achieved. In short, sharing representations in the service of achieving solutions for the several types of problems discussed earlier becomes characteristic of the evolution of well-formed, collaborative systems.

Thus far, we have been assuming a situation in which A and B are in simultaneous confrontation with some other event X with respect to which appraisive, designative and prescriptive representations are shared in the service of socialized goal-attainment. In principle, the state of affairs or sequence of events referred to by X remain available for solving the error-control problems referred to earlier; i.e., "updating" the shared representations. As we mentioned earlier, the process of updating involves feedback which relates representation and "reality." When X is not immediately available for purposes of up-dating reference, when "feedback" is delayed, there is obviously a source of potential and serious disabling with respect to achieving solutions for error-control problems and, therefore, the resolution of the goal-attainment problem.

Similarly, a disabling condition can characterize a collaberative system when the semiotic process involved in sharing representations delays reciprocal "map-matching." When A and B are neither in simultaneous confrontation with X nor are they in simultaneous confrontation with each other, the conditions are present for delays in both types of "feedback." Human collaberative systems are frequently characterized by delays of both kinds which constitute new problems to be solved. In any case, when such delays are present, the higher-order system is notoriously hard to keep stable. Even with only two persons, the familiar example of one person trying to keep out of the other's way in a narrow street reveals the insidious power of a time lag to frustrate mutual adjustment. In larger collections of persons, or systems, simultaneity of confrontation is largely impossible and the associated delays become perennial problems to be solved.

One last comment seems appropriate to the discussion. When, as the result of reciprocal semiotic behaviors, co-orientation has been achieved (representations are shared and matched) we may speak of the actors having achieved _symmetrical_ semiotic states. In some settings, the actors may also achieve symmetrical non-semiotic behaviors as well. Although symmetrical semiotic behaviors is at least conceivable in larger collections, symmetry in action is frequently out of the question. That some form of ordering (i.e., asymmetry) is required in the several problem-solving functions to prevent vicious closed loops and deadlocks from forming seems inescapable. This calls for the central coordination of internal communication and relevant action.

In such aggregates, then, we are confronted with a topological problem of second order. We began by thinking of goal-seeking systems as a network of interactive elements, which had to evolve an organizing hierarchy in the interest of mutual survival. A distribution of specific semiotic and non-semiotic behaviors among the membership is required in accordance with an organizational "prospectus." The prospectus may be thought of as a complex representation of the action-space of the aggregate, the goals and goal hierarchy of the aggregate, and the action to be taken both differentially and collaterally to monitor the "is-ought" discrepancies, and the internal communication required to reduce the discrepancies that may occur. One of the principal differences between such ordered systems when composed of humans as opposed to machines, is that each of the human components represents a replication of all of the essential functions for a goal-directed system. Apart from the technology of specialization, each human is in principle capable of carrying out all of the functions of the system - and he is capable of constructing a representation of this capability. One of the essential problems, then for human organizations is the matter of distributing the essential functions in such a manner that the roles prescribed for each member are consistent with his own appraisive representations of himself at any given time, and that the whole remains upon to negotiation.

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PART II

TRAINING IN INTERPERSONAL COMMUNICATION[*]

F.R. Fosmire and F.L. Brissey

In the preceding discussion we have sketched preliminary view of the human being as an "adaptive system" whose well-being is dependent on achieving solutions for several kinds of problems. In this context, interpersonal communication was treated as a process in which semiotic events serve as "messages" which mediate problem-solving. We have briefly examined such messages as instruments of _control_ in which the message-directed behavior of one individual serves the goal-attainment interests of another. Similarly, we have examined messages as semiotic behavior which _enables another_ to function more effectively as a goal-attainment system. Presumably, the phrase _communication problems_ refers to: (1) deficiencies in achieving control over the behavior of others through semiotic manipulation; or (2) conditions in which enabling messages either do not facilitate or actually interfere with goal-attainment. This approach to the question of communication "disorders" serves to make clear the importance of identifying (1) the nature of the problem for which a solution is required; (2) the object or event with respect to which the problem is said to exist; and (3) the system whose functioning is dependent upon achieving a solution for the problem in question.

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[*] This section of the report is based in part on an unpublished paper by F.R. Fosmire, F.L. Brissey and C.S. Keutzer, "Characteristics of Matrix Tasks Employed in 'Tasks Directed Learning'."

The following discussion explores Task-Directed Learning (TDL) as an approach to training in interpersonal communication in which the participants first generate "specimens" of their own communicative behavior and then turn to a critical examination of this behavior. There are two basic objectives in the TDL approach: (1) to assist the participants in acquiring a more complete understanding of the process of interpersonal communication and (2) to provide a setting which may facilitate learning to manage the process more effectively. The first objective places the participants in the role of an observer whose task (in principle) is to construct designative representations of the process. The second objective focuses on the construction of prescriptive representations, and this necessarily presupposes certain solutions for the participant's appraisive problems. This distinction between the two basic objectives of the TDL approach additionally identifies two quite different roles for a TDL sponsor. He may arrange the laboratory environment and activities for the participants so as to maximize the likelihood of displaying salient properties of the communicative process and then participate only as a designative inquirer; or, having structured events in this way, he may then participate prescriptively in which case he must also participate in the solution of appraisive problems. Thus, the particular characteristics which may emerge as properties of TDL in a given instance cannot be described in terms of the operations alone - the semiotic behavior of the sponsor must also be considered.

The TDL approach employs small groups of from two to no more than twelve to fifteen individuals. A key assumption of the approach is that the effectiveness of the group as a problem-solving system will increase as individual team members learn to represent the process of interpersonal communication more completely and more precisely. For long-term working relationships we further assume that the group's survival as a coactive problem-solving system is dependent upon the competence acquired by the group in functioning as an integrated goal-attainment system while preserving the integrity of each member as an integrated sub-system. In other words, the group must learn to become "technically competent" in the sense of achieving solutions for the problem or problems calling for the activity of the group, and it must also provide a net positive reinforcement for the behaviors required of its members. Brown has suggested essentially the same criteria:

> Any group or organization has two principle problems to solve: the achievement of the purpose for which it exists, the business of the group; and the provision of personal satisfaction to individual members sufficient to keep them together, to maintain their interdependence. (Brown, p. 685)

In an earlier section we pointed out that the performance of a coactive group may be analyzed (in principle) in at least two ways. We may describe the nature of the problem with which the group is initially confronted, the group's performance in achieving a solution for the problem, and the adequacy of the solution which is achieved. On the other hand, analysis may emphasize the nature of the problems which emerge in the course of the group's functioning as a coactive system. Clearly, both analytic emphases are essential for a complete understanding of the group problem-solving process. TDL is designed to encourage an examination of the linkage between "internal" problems and problem-solving techniques and the effectiveness of the team in solving its "external" problem.

For example, a team may be confronted with the problem of learning how certain environmental events are structured, and this may entail developing a procedure for assuring that each member has learned the same thing (the higher-order problem of designative consensus). One solution (prescriptive) for the team's internal problem may take the form of constructing and comparing designative representations purporting to replicate the structure of the events in question. Another solution may require one member (or subset of members) to display his representation and for the others to provide "matching signals." The second plan may be considered a less time-consuming but riskier prescription than the first. If the members of the group are not in appraisive consensus with respect to risk-taking, a new problem (achieving appraisive consensus) will have emerged calling for reciprocal semiotic address to the appraisive hierarchies of each of the members.

Although it seems plausible to argue that the resolution of internal problems is logically prior to the resolution of external problems, "trade-offs" in one form or another are exceedingly common - and this identifies still another problem to be solved. In any case, detecting, analyzing and solving emergent internal problems is unusually difficult in the course of semiotic interaction directed to solving an external problem. TDL procedures are therefore designed to encourage overt self-reflexive communication immediately following the termination of a group's problem-solving activity.

In this phase of communicating about their own communication, the members of the group are encouraged to "focus" on the semiotic behaviors observed to actually occur in the group setting. In this phase of a TDL program the participants are joined by others serving as observers, and they also utilize audio and video replays against which to compare their representations of the process. Thus, the group members rejoin in a process of meta-semiotic inquiry guided by the questions (1) "What actually occurred?" (2) "What was preferred?" (3) "Is there a discrepancy?" and (4) "How might the discrepancy be reduced?"

In the course of meta-inquiry the participants are provided with a somewhat specialized vocabulary as an aid in constructing representations of critical events or salient properties of the group's behavior. Many participants, particularly in the early stages of a TDL program, appear to experience difficulty in shifting quickly and smoothly from the position and language of a participant to that of an inquiring observer. One of the fundamental and theoretically essential goals of TDL is to develop facility in the shift from participation to self reflexive inquiry.

General TDL Procedures

For purposes of clarity, we have divided the TDL procedures into three main categories: _tasks_, _exercises_, and _sociometrics_; and the distinctions among them are made explicit elsewhere (Fosmire & Keutzer, 1968). In this paper we will be concerned only with "tasks" -- those procedures which are sufficiently objective and quantifiable to be used, when needed, as assessment devices and for which we can specify adequacy of performance (in time-and error-scores) relative to the functioning of individuals or groups and/or relative to the performance of a hypothetical "ideal" problem-solver. We will limit even further the scope of this discussion by dealing only with those TDL tasks which employ a matrix apparatus called the "VOCOM." Before describing this apparatus and the various kinds of tasks associated with it, some more general considerations in the use of all TDL tasks should be briefly mentioned:

1. There is a very large number of variations of each of the tasks which we describe.

2. There are a number of situational variables that can be manipulated in relation to any given task. (See "Important Dimensions of Variation.")

3. We generally use a teams-within-groups or "nested sets" design when using the tasks. This design has many training advantages, chief among which is the allowance for the "fishbowl" situation wherein some participants observe while others perform the task.

4. We "debrief" from every procedure; that is, we encourage participants to share their observations of, and reactions to, both semiotic and non-semiotic events occurring during the task itself. Of especial concern are two important components of interpersonal feedback: description of participants' own "feelings" and descriptions of behavior of others to which they were responding.

5. We use a standard observational set, exemplified by the TDL Observation Guide (presented below), for all tasks.

TDL Observation Guide[*]

I. Leadership/followership.

A. Who initiates what behaviors?

B. How do others respond to the initiation? (The "group-control" observation-guide might be referred to for specific examples of responses to initiation.)

C. Who controls (or constrains) others' behavior? How?

II. Communication.

A. Who talks to whom?
   1. Who responds to whom?

B. What are the individual differences in level of verbal activity?

C. What communicative behavior is task-centered?

D. What communicative behavior focuses on interpersonal process? (The observation-guides for "task-centered process: and "interpersonal process" might be referred to for specific examples of behaviors in each category.)

E. How do team members attempt to persuade one another?

F. What are examples of verbalizations which contribute neither to task-effectiveness nor maintenance?

III. Decision-making.

A. In general, how does the group know when it has reached a decision? (The "group-control observation-guide might be used here also.)

B. How are strategic decisions made? E.g.
   1. Division of labor (role-differentiation)?
   2. Devising procedural rules?
   3. Procedures for resolving conflict?
   4. How much risk to take?

C. How are tactical decisions made?

IV. Conflict-management/conflict-resolution.

A. Examples of conflict being used constructively?

B. Non-constructive reactions to conflict...e.g.,
   1. ordinary individual defense-mechanisms?
   2. scapegoating?
   3. *post hoc* redefinition of goals?
   4. intensification of inter-group conflict?

---

[*] Developed by Fred Fosmire & Carolin Keutzer, November 1967.

The VOCOM Apparatus

The many variants of the original VOCOM apparatus (Brissey, 1964) all have the following characteristics in common:

(1) they comprise an n x n matrix of points which can have one of two states;

(2) the state of every point can be manipulated;

(3) some operation on the matrix produces information about the state of any point, i.e., produces "situational feedback."

In "V. Important dimensions of variation," we describe how the VOCOM apparatus can be modified to present problem-solving teams with different sorts of problems. In this section we will describe four apparatuses which vary in complexity and expense.

VOCOM Mark I.

This apparatus is housed in a cabinet approximately 30½" high, 25½" wide and 6" deep. A matrix of 400 audio jacks (2 conductor, with SPDT switch) is installed on the front panel in a 20 x 20 square. Each jack is wired to a corresponding control switch on the rear panel (SPDT; center position off). The rear-panel control switches are therefore arranged in a 20 x 20 matrix corresponding to the arrangement of audio jacks on the front panel.

Two pilot lamps are mounted on the front panel, one near the center top and the other near the center bottom. When a rear-panel control switch is in the "up" position, and a special conducting plug is inserted in the corresponding audio jack, both pilot lamps can be illuminated by pressing one of the "prediction" switches on the front panel. When the control switch is in the "down" position, only the bottom pilot lamp is turned on by depressing one of the prediction switches. By this arrangement, various displays of "two-light" (or one-light) jacks can be pre-selected.

Approximately 2½" to the left and right of the lower pilot-lamp are mounted spring-loaded toggle switches (SPDT center-position off); the switch on the left is marked "one light" and the switch on the right is marked "two light." With a preselected display "switched in," the team is provided with a metal-tipped "probe" and then instructed in the operation of the apparatus.

In brief, the team members may select any jack they wish and insert the probe. Then they decide whether that selected jack will turn on only the bottom pilot-lamp, or both the lamp at the bottom and at the top. If they predict that the selected jack will turn on only the bottom lamp, the prediction is recorded by pressing the switch marked "one light," but if they predict the alternate condition, they press the "two light" switch. With the probe in place, pressing either of the two switches will turn on either one or two lights, depending on the setting of the rear-panel control switch. Thus, the act of registering the prediction also provides information regarding the state of the selected jack.

The series of predictions and actual events are automatically recorded on a four-channel event-marker with the chart drive operating at 1"/minute. Performance-time and prediction errors can be read directly from the chart. With this arrangement, once a team is instructed in the operations, they may be left to work alone if one desires a no-audience condition.

The team's task is to minimize the number of prediction-errors made in learning the pre-selected arrangement of one- and two-light positions.

For certain experimental or learning purposes, the team may also be equipped with color-coded markers (wooden pegs) with which to mark each jack tested, thereby producing a visual display of the actual states of the jacks already tested. Using markers which are not color-coded allows a record to be displayed of the positions tested but not the actual states of the jacks. In this case, the team is required to "store" the information yielded by the sequence of testing.

VOCOM Mark II.

This model uses a 12 x 12 matrix of clear lucite single-throw toggle switches, on two-inch centers, mounted in a gray aluminum field, 36 x 36 inches. A corresponding matrix of lucite switches on the opposite side (back) of the apparatus has been wired so that when any switch is depressed, its counterpart on the front panel is activated. An activated switch will light up when thrown; a non-activated switch remains unlighted even when depressed. The use of lighted switches reduces the likelihood of error in switching in the preselected display. Because of the ease and speed with which the structure of lighted switches can be changed, this apparatus has advantages over VOCOM Mark I in laboratory-learning.

VOCOM Mark III.

This equipment was designed primarily for training. It is cheaper, lighter, smaller, hence more portable than either of the first two.

This equipment employs masonite peg-board as the team's working surface which is mounted in a cabinet approximately $22\frac{1}{2}$ inches square and $2\frac{3}{4}$ inches deep. One side of the cabinet is hinged to allow access to a sliding "shelf" which contains a 12 x 12 matrix of holes corresponding to the holes in the team's working-matrix. A display is arranged by installing a heavy cardboard "template" on the sliding shelf. In effect, the template serves to block some of the holes and not others. Insertion of a cover-sheet of plain newsprint between the subject's matrix and the template-shelf prevents team members from visually detecting the template-contours.

The team's task is again to specify the positions of the open, or unblocked holes with as few errors as possible. In some training operations a team is given a supply of pegs in two different colors. One color is used to predict open matrix-positions and the other to predict blocked matrix-positions. In this case, the template-shelf is located close enough to the working surface to allow each peg to indicate the actual state of the position. In other training operations, the pegs are used merely as markers and the subject is provided with a probe for purposes of determining the actual state of each position. The template-shelf is then dropped to a lower position to insure that the markers do not provide situational feedback. The use of these variations in the context of a training laboratory are more fully described later in the report.

VOCOM Mark IV.

This version of the apparatus is the cheapest, lightest, and least elegant. It is a 12 x 12 matrix of die-cut circles, the size of a quarter, in a 20" x 20" cover-sheet that is glued to a heavier cardboard backing on which the display is printed. Subjects can remove any circle in the matrix by pinching it and tearing out. In other words, the apparatus is a large "punchboard."

In quite general terms, the likelihood of error in performing any of the Vocom tasks is a function of the "complexity" or "structure" characterizing the display with which the group is confronted. Whether the task requires "learning" the display through sequential decision-making or communicating about iconic representations in the form of "maps," structure is a factor of considerable importance. Just as complexity in a visual display may have differential effects on discrimination and recall, it may be expected to bear on important relation to encoding and decoding operations in verbal communication. For experimental and training purposes, we have worked with four approaches to complexity (or structure): 1) statistical constraints which influence the ratio of display positions, but not the selection of display positions; 2) grain; 3) iconic displays such as the letter "X"; and 4) sequential displays in the form of "tracks."

Let us consider each form of constraint more concretely.

Statistical. The task for a team confronted with a statistically constrained display is to detect the imbalance in a sequence of binary events and to develop a prediction strategy to maximize the probability of being correct in subsequent decisions. The only "structure" holding among the individual events in the sequence is in terms of the relative frequencies of the two events. The Prediction problem (See page 122) with a randomly generated but probabilistically imbalanced display is a close analogue of the prediction problem employed in statistical learning studies (e.g., Estes, Siegel, etc.).

Grain. Higher-order redundancy can be introduced into the displays by assigning, *a priori*, common fates to sets of points (switches or jacks) in the matrix, by treating sets of points--e.g., 2 x 2,--as a variable (Attneave, 1959; Garner, 1962). Dorfman uses the term "grain" to refer to the imposition of a larger unit matrix on a base matrix (1965). The following figure illustrates a "three-grain" display in a 12 x 12 matrix.

X	X	X	X	O	O	O	O	O	O	O	O
X	X	X	X	O	O	O	O	O	O	O	O
X	X	X	X	O	O	O	O	O	O	O	O
X	X	X	X	O	O	O	O	O	O	O	O
O	O	O	O	X	X	X	X	X	X	X	X
O	O	O	O	X	X	X	X	X	X	X	X
O	O	O	O	X	X	X	X	X	X	X	X
O	O	O	O	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	O	O	O	O
X	X	X	X	X	X	X	X	O	O	O	O
X	X	X	X	X	X	X	X	O	O	O	O
X	X	X	X	X	X	X	X	O	O	O	O

Representation. This form of constraint is almost self-explanatory. Any figure which has meaning for the problem-solving team can be used. Letter and number signs or simple geometric figures are more easily recognized in the relatively coarse-grained 12 x 12 matrix than an iconic representation of some object. The larger the matrix, the greater the range of objects which can be represented by distributions of discrete space points.

Sequential. The only constraint here is continuity. The problem-solver knows in advance that one and only one of the points contiguous to a known point has the same state as the known point. In this case, complexity is a function of the number of runs, length of runs and directional changes in a particular track.

Some VOCOM Tasks and Commonly Observed Phenomena

Two basic problems are involved, either for individuals or for groups, in each of the tasks which will be described: (1) the inductive determination of "structure" (and how to use knowledge of structure to minimize errors), and (2) communication about structure. When a group attempts to solve some of the tasks coactively, they encounter additional problems of consensus.

The Discovery and Prediction tasks are principally designative problems in structure-induction. In the Split-team Communication and the Stimulus-Discrimination Tasks, the structure is fully known by some and totally unknown by others. For this reason these tasks are regarded primarily as communication problems. All of the other tasks involve both structure-induction and communication. Some, e.g., the Error-estimation task, emphasize achievement of a consensus-solution.

All of the tasks have the following characteristics in common which make them useful in the study of group problem-solving, decision-making, communication, and conflict-management:

(1) They are inherently interesting. Participants have spent more than an hour on each of these tasks without becoming bored.

(2) They provide an objective, easily understandable, measure of group-performance.

(3) Within gross limits, a rather wide range of task-difficulty can be predicted and manipulated according to known physical characteristics of the display.

(4) Since the over-all problem can be articulated into a large number of molecular decisions (or molecular messages in the case of a communications task), one task provides many examples of the phenomena characteristic of a given problem-solving team.

(5) Also, because the total task is comprised of many molecular problems, it provides an excellent opportunity for learning *in situ*. As participants become increasingly aware of their characteristic inter-actional behaviors, they have many opportunities in the task to practice alternative behaviors.

The Discovery Task

The essential problem for the group in this task is to place pegs (or activate switches) only for the "display" positions of the matrix, and to *avoid* placing pegs in non-display positions. Thus, correct-incorrect feedback must be provided for each position in the matrix, and the team is to select positions which they think will provide correct feedback. This makes the task equivalent to a retrieval problem in which only the 'pertinent' items are to be retrieved from the matrix and for which two kinds of error are possible; errors of commission and errors of omission.

Several instructional sets may be used with this task, e.g., minimizing error, minimizing time, or optimizing an error-time trade-off. On the other hand, the instructions may shift the goal-setting operation to the team itself. (The following instructions apply to VOCOM apparatus Mark III, a version employing wooden pegs and a masonite pegboard matrix.)

Discovery Task - Instructions for Team Goal-setting

> Some of the holes in the board are blocked and some are open. Whether a hole is blocked or open may be determined by placing a peg in the hole. If the hole is blocked, the peg will stand up. If the hole is open, the peg will go down.
>
> You are to search for open holes by placing pegs in the board. An open hole will be marked with a peg that goes down. In locating the open holes, you should try to make as few mistakes as possible. Each mistake will be marked with a peg that stands up.
>
> You may stop your search at any time you choose. However, there are three things to keep in mind in making that decision: 1) you will be scored on the total number of open positions you are able to identify; 2) you will be scored on the number of errors you make in the process; 3) you will be scored on the amount of time you take.
>
> Please let us know when you decide to stop.

The discovery task was designed to provide opportunity for the team to explore several levels of decision-making. The nature of the problem allows goal-setting, for example, to emerge as a matter of explicit, coactive consensus, or to remain implicit, thus increasing the likelihood of prescriptive conflict.

The problem provides an opportunity to observe the consequences of sharing in the process of discovering structure as opposed to "following the leader" or of proceeding by an individualistic, parallel, mode of operation.

The problem requires the team to decide when to terminate their retrieval efforts, and the nature of the problem is such that to completely resolve the team's uncertainty regarding the matrix insures making a maximum number of commission errors, but to minimize commission errors requires some positions in the matrix to remain untested. Recognition of this inevitable trade-off often exposes individual differences in risk-taking and identifies the emergent problem of appraisive conflict.

Finally, the problem was designed to illustrate the influence of matrix-structure on both the retrieval-effectiveness of the group and the nature of coactive behavior that may emerge as a function of structure. Displays of relatively high structure (low complexity) generally yield greater retrieval success and fewer internal problems to be solved than do displays of low or moderate structure (high or moderate complexity).

Common Phenomena

It is extremely common for members of the group to agree very early in the task that they should be looking for a "pattern." Typically, it is not made clear, however, what is meant by the term, nor is it usually explicitly recognized that an extremely large number of displays might be appropriately referred to as a "pattern."

Many groups spend as much as five minutes speculating about the nature of the "pattern" of the display before obtaining any information (situational feedback) from the apparatus. Since there is no informational basis for selecting among the various hypotheses which are offered, the group usually follows the lead of the most vocal and confident member. It is highly probable, of course, that his hypothesis is wrong. How quickly the group rejects his leadership depends upon the relative passivity of the remaining members of the group. In some groups in which there are two or more persons competing for influence on decision-making, the initial leader may be displaced with the first occasion of infirming situational feedback. At that point, the group may develop new hypotheses coactively, or it may allow the next most dominant member to make decisions until his hypothesis is infirmed. Continued shifting of leadership (and a corresponding acceptance of hypotheses solely on the basis of the individual's dominance) is evidence that hypotheses are not being developed coactively.

Some groups solve the problem of arriving at a group decision by converting this task into a problem for n individuals working in parallel. Each member works on some portion of the matrix, without attending to what the others are doing. This sort of individualistic, parallel performance typically yields high error and low time-scores. If the members begin in a parallel fashion but stop to take stock as soon as one member reports perceiving "structure," and if they then proceed coactively, good time- and error-scores can be obtained. The group that is overly analytical early in the task typically takes a lot of time since the members keep themselves from obtaining the constructive information required to detect the structure or the display.

Most groups default in setting goals in this task, i.e., whether to optimize time-score, or harmonious working relations, etc. The decision to stop work usually is made with little apparent conflict, although observers might be hard pressed to describe just how the decision was reached. Individual differences in preference to stop in the face of unresolved uncertainty (in the unexplored portions of the matrix) are taken as indications of one aspect of risk-taking.

The Prediction Problem

The apparatus and feedback provisions for this problem are essentially the same as those for the Discovery problem. The operations are somewhat different, however, in that the task is to predict one of two states for each matrix position. This requires a procedure for registering the team's predictions in advance of the information-producing test. In one version of the apparatus (Mark I) the team registers its prediction by inserting a metal probe in a telephone jack and pressing one of two prediction-switches. An event recorder accumulates the data on correct and incorrect decisions as well as rate of decision-making. In the Mark III version of the apparatus pegs of two different colors are used to code the predictions.

The problem requires a number of decisions equal to the number of positions in the matrix and, in contrast to the Discovery problem, resolves all position-state uncertainty by the time the problem is completed. The error-score in this case is the total number of incorrect predictions, which is inversely related to the structure of the display.

Although this problem is quite similar to the Discovery problem in many respects, the essential difference is that there is no unresolved uncertainty. The team is not required to face the "stop" decision and therefore individual differences in risk-taking will not be recognized. For these reasons the Prediction problem is somewhat less demanding and may profitably be used early in a TDL program.

Our observations of groups working on this task confirm many of the statements of Maier (1967). Groups usually obtain error-scores which are comparable to those for individuals working alone, however, they take much more time. Only those groups which have seriously attempted to identify and modify irrelevant time-consuming operations (and which show evidence of improved functioning on other tasks as well) learn to perform as fast as individuals without inflating their error-scores.

Prediction Problem Instructions (VOCOM Mark III)

> Some of the holes on the board are blocked and some are open. If you place one of these pegs in a blocked hole it will not go all the way down, but if the hole is open it will seat well into the hole.
>
> Your task is to predict which holes are open and which ones are blocked and to make as few mistakes as possible. Proceed by choosing one of the holes, if you think the hole is blocked place a red peg in the hole, but if you think it is open place a white peg in the hole. If the hole is actually blocked the red peg will stand up but if it is open it will go down.
>
> Remember,use the red peg when you predict the hole is blocked, use the white peg when you predict the hole is open. Standing white pegs are errors and seated red pegs are errors.
>
> Work as quickly as you can and with as few errors as possible. You will be scored for both time and error.

Many of the phenomena which are observed with the Discovery problem are likely to appear also on the Prediction problem, as the tasks present the same opportunities for distributed and coactive decision-making. Again, there is the common phenomenon, more likely with a team, of a highly analytic approach to the task early in the game.

It might also be noted that the "set" to discover a pattern appears to be deeply embedded and is extremely resistant to change. This is seen most dramatically when the team works on a randomly generated display with a probability of .50 of either alternative at each matrix position (i.e., that there is no structure at the matrix level). The team very frequently expresses disbelief, and often carries the search for a pattern to the very last decision, despite an accumulation of information revealing the randomness of the display. If and when randomness is identified, the team members not infrequently complain of having been "tricked."

The Split-team Communication Task

This task involves the same apparatus as the Discovery Task. The procedure is different in that the team members are given all the display information required to solve the problem. Typically a four-person team is divided into two pairs and each pair is given one-half of the total information in the form of a "map" of the display.

After instructions are given, each pair receives a map depicting unambiguously either the upper or lower half of the matrix. The team has x minutes to memorize the map (the amount of time varying with the complexity of the display), after which one pair goes to the apparatus to "discover" the display in the half of the board not included in their map. The other pair, meanwhile, is available to answer questions or to volunteer designative or prescriptive messages. They cannot, however, observe the performance of the first pair. When the first pair completes their half of the display, they trade places and exchange roles. Now they are the "perfectly informed consultant" for the second pair.

Rationale. This procedure, as an introductory communications task, was designed to have the following characteristics:

(1) The content of communication is totally neutral (objective), allowing participants to observe the things they may do to interfere with the exchange of enabling messages, even when they are about impersonal objects and events.

(2) The task provides an objective index of the communicative competence of the system which can be compared with the scores of other teams. As with the Discovery Task, however, the emphasis is on processes of semiotic interaction rather than the objective scores.

(3) It highlights the desirability of "active listening." Because the person volunteering information cannot see what the other is doing with it and gauge his comments accordingly, performance suffers unless the receiver paraphrases the transmitter's messages, or otherwise offers constant feedback to the transmitter.

(4) It demonstrates--to a dismaying degree--that it is misunderstanding rather than understanding which is the common state of affairs. The realization that communication is impaired on even such a simple task provides great impetus for participants to develop more effective communication.

Common Phenomena

The greatest confusion, as in the Stimulus Discrimination Task, is likely to stem from lack of a common descriptive language (See Stimulus Discrimination Task). See also the remarks under "Important Discussions of Variation--Situational Feedback."

Shared Map Task

We have developed several versions of this task, the newest and most promising (and least tried) of which is the Real Estate problem developed by one of our associates, Dick Diller. All are communications tasks in that the group has all of the information that it requires for error-free performance, if the members can only share the information effectively.

The task requires a VOCOM apparatus and four display-maps based on 12 x 12 matrices.

The instruction for Real Estate Problems I and II will illustrate the basic principles in this task.

Real Estate Problem I

Imagine your team to be a real estate firm commissioned to purchase lands appropriate for grape culture for United Vintners, Inc. Ideally, such land should be characterized by adequate rainfall, fertile soil, gentle slopes, and adequate subsoil drainage.

Inadequate water can be compensated for by irrigation wells. Infertile soil can be compensated for by soil building practices, fertilizers, etc. Hilly land can be terraced. Inadequate drainage can be corrected by laying drainage pipes. United Vintners is willing to bear the expense of no more than one such corrective program.

Your assignment is to identify those sections of land (represented by the Vocom matrix) which are appropriate for grape culture with the application of either no corrective procedure, or only one such procedure.

Available to you is a map displaying the pattern of fertile lands, a map displaying the pattern of adequate rainfall, a map displaying the pattern of gently sloping land, and a map displaying the pattern of adequate subsoil drainage conditions.

Real Estate Problem II

Imagine your team to be a real estate firm commissioned to purchase lands for your clients.

One client, a public utility, requires a site for an atomic power plant. The site must have adequate water (a lake) available to carry off excess heat. It must have live rock near the surface to provide adequate foundations. It must be near a railroad in order that heavy equipment be inexpensively moved into position, and near an urban center to minimize distribution costs.

A second client seeks a site for a waterfowl sanctuary. It must be located on a lake, of course. Soil must be deep and fertile (i.e., stone not near the surface). It must be relatively remote, i.e., non-urban and away from railway arteries.

A third client seeks a site for a sanitorium in a dry, quiet (away from railroads, etc.), fertile area. It must be in an urban area in order that adequate services be available.

A fourth client, the C.I.A., is seeking a test site, remote from transportation routes and urban populations. The area must be dry and must provide live rock near the surface to support the large structures projected.

A fifth client is seeking a site for a wheat elevator. This facility must be placed in a fertile, rural area, and be near a railway. Humidity must be low; thus it must not be placed near a body of water.

Available to you is a map displaying the distribution of lakes, a map displaying the distribution of urban development, a map displaying the distribution of surface projections of live rock, and a map displaying the pattern of rail service.

This task is similar to the Split-team task but much more complex. First, the team must deduce from the instructions the relationship between the individual "maps" and the display in the VOCOM apparatus. Team-members must then find methods for effectively communicating with respect to the information they possess.

Common Phenomena

In the shared-map tasks, generally, performance is impaired for the same reasons as mentioned for the Stimulus-Discrimination and Split-team Communications tasks. In addition, however, the shared-map task allows a greater opportunity to compete for dominance. Typically, stronger emotions are aroused. Team-members are more likely to lose confidence that they are recalling their maps correctly, or that their partners are recalling correctly. In general, the task requires much more exchange of information, and this must occur among all members of the team--even those who are least competent at communication. There are many more opportunities for misunderstanding. As with the Split-team task, the effect often is to heighten awareness of the difficulties of effective communication, and to elicit messages assessing the competence of other group members.

Stimulus-Discrimination Task

The stimuls materials are photographs of matrix-displays of two, three-, four-, six-, and 12-grain matrices superimposed on a 12 x 12 base matrix. In the total set of cards there are six different displays in each of the following grains: 3, 4, 6, and 12; and four different two-grain displays. Each participant in this task may receive from six to ten cards (photographic prints) in his packet of materials.

Instructions Stimulus-Discrimination Task

A set of cards will be distributed among you. One card in the set is a singleton,i.e., it is unique. In other words, each card in the entire set has one or more duplicates, except the singleton card. Your task as a group is to discover the singleton card in the entire set. If you declare incorrectly, that will be scored as an error and you will be allowed to proceed until you have identified the correct card.

You may organize yourselves any way you wish to complete this task, with only the following restrictions: (1) you cannot show your cards to another member; (2) you may not pass cards to another member; (3) you must not look at another member's cards; (4) you cannot draw pictures or diagrams of the designs; (5) do not refer to the numbers on the back of the cards; and (6) do not pool your discards (i.e., keep your discards in a separate pile). You may talk any way you choose.

You are scored for both time and errors so work accurately and as fast as you can.

Whereas the Prediction and Discovery tasks can be converted by the group into individual performances with the remainder of the group observing, the Stimulus-Discrimination task cannot be solved without some of the more passive members of the group taking initiative in communication. Almost inevitably someone will suggest that members break into pairs or trios, identify and discard all the cards which they have in common, then work as one group with the much smaller number of cards that remain. Not infrequently, a group will follow this procedure right up to the final step, when it becomes obvious to almost everyone that the strategy will work only if every person double-checks all of the cards in his discard-pile at the same time he is checking the cards which he has not discarded. Usually, at least one member foresees the pitfall in this approach but either cannot describe the disadvantage or is not pursuasive enough to influence the group.

By sensitizing the group to some of the consequences of markedly unequal participation, the Stimulus-Discrimination task has the effect of temporarily inhibiting the most talkative members of a group. One result is that most members--even the passive ones--become aware of the resources which are not being used by the group.

Common Phenomena

Most of the problems encountered with this task are due to inadequate "gatekeeping" in the group (i.e., due to failure to insure that everyone has an opportunity to participate in all states of the solution).

We might differentiate between strategic and tactical errors. The most common strategic error is to fail to realize that the task cannot be solved through a "parallel" approach. A second common strategic error is to allow the more dominant members of the group to determine implicitly the terminology to be used in describing the cards and the order in which to work through them. Without a common descriptive language a group is very likely to find each of the more dominant members using his particular favored terminology--to the confusion of at least one other person.

For example, in a 12 x 12 matrix, a four-grain display--that is, one that results from imposing a 4 x 4 matrix on the base matrix--is comprised of 3 x 3 squares, and a three-grain matrix produces 4 x 4 squares. It is very easy to confuse statements about boxes which are 4 x 4 and statements about dividing the base matrix into fourths. Similar confusion results from lack of agreement as to general level of molarity/molecularity, or how literal or metaphorical to be in describing displays. One person, for example, may prefer to describe displays in terms of their gestalt (e.g., "sort of a fat, distorted L, lying on its side") while others want a point-for-point delineation.

Other sources of confusion are terms about location ("northwest corner," top-right quadrant," "a red square in the upper right quadrant of the upper left sector") and about order of scan ("proceeding clockwise from the upper right corner," "going across the top line and doubling back on itself").

A member of one group, in which several dominant members were using idiosyncratic terms of reference, became so confused that he asked, "Wait a minute! Is 'horizontal' up or down?"

The most common and serious tactical errors might be described as "passive listening," and silent acceptance of nonunderstanding. If one member describes a card, and another replies "I've got that one; let's throw it out!" the group may be making two mistakes. First, the member may not be hearing the description correctly but he does not paraphrase so no one catches the error. Second, there may be a third card in the set. If a more passive member has the third card, he may fail to speak up to double-check on his suspicion that he holds the card, only to run the risk of erroneously identifying that card as the singleton later in the task.

Three-phase Task

This task combines features of the Discovery, Prediction, and Split-team Communication tasks, and also emphasizes the utilization of special abilities in the group. It usually is assigned to a group after the members have had experience with the other tasks, have seen how they performed, and have had ample opportunities to analyze their performance.

The materials are matrix apparatus(es) and paper and pencils.

Instructions Three-phase Task

> This is a resource-utilization problem. As a group, you have the problem of deciding who to assign to each phase of this task, and of deciding how you want to organize the procedures for each phase. You may select any number of persons to work on each phase of the task, with this restriction only: no person who works on phases 1 or 2 can work on phase 3.
>
> Phase 1 is a Prediction task. The person or persons who work in this phase will have the task of predicting the state of every position in the matrix. The adequacy of their performance will be indexed in terms of time and prediction-errors.
>
> Phase 2 is a communications task. The person or persons who work in this phase will have the task of encoding a message, using English words (not special symbols, maps, or drawings which are in effect iconic representations of the display), which will be left for the person or persons in the third phase.

> Phase 3 is a Prediction task again. This time, however, the team has carefully composed instructions which are designed to facilitate the team's performance.
>
> The over-all index of performance is total time (over all three phases) and total errors on phases 1 and 3. You have an hour to decide how you want to tackle this task.

The Three-phase task is designed to build on the simpler tasks. Whereas the Discovery, Prediction and Split-team tasks involve only four or five members assigned to teams arbitrarily, the Three-phase task is presented to an entire group of 12 to 15 persons. The opportunity to select the teams for each phase and to organize their efforts makes this a resource-utilization task at the level of the entire group. The actual performance of the three teams is evidence of their effectiveness in recognizing and utilizing resources.

In selecting the persons for each phase of the task, a group will select wisely only to the extent that they have been validating the inferences they make about one another, both consensually and against external (task-performance) criteria. Even if they have fairly accurate impressions about one another's group problem-solving abilities, group-members will be able to share this information only to the extent that they know how to and feel confortable in giving and receiving interpersonal feedback. Because the group has much freedom in deciding how it will use its resources for this task, it is all the more important that the group arrive at a fairly accurate consensus as to who can do what well, with whom, and under what circumstances.

Common Phenomena

We cannot describe common phenomena for this task as it seems that every group approaches the task in an idiosyncratic way. Our impression is that the groups which have developed the highest levels of interpersonal trust also develop the most ingenious approaches and obtain the best performance-scores. One group, for example, impressed with how well the members of one team communicated with one another, assigned two members of that team to phase 2 and the other two to phase 3, on the assumption that they would be very efficient at encoding and decoding one another's messages. Another group attempted to capitalize on the fact that "observers" of a team frequently recognize the solution prior to anyone on the problem-solving team. They had observers for each phase of the task and the arrangement worked well in decreasing both time- and error-scores. That particular group wanted to follow the procedure for the additional reason of involving every member in the task.

Error-estimation Task

This task is done at three levels: (1) by individuals working alone, (2) by four or five person teams, and (3) by the entire group. Individual solutions are compared with team solutions which are in turn compared with the solution of the entire group.

The task cannot be used meaningfully until after a group has had experience with one or two structure-induction problems, preferably including the Prediction task. The stimulus-materials consist of cards depicting one each of two-, three-, four-, six-, and 12-grain randomly generated displays, with half of the matrix-positions filled (except in the case of the three-grain where exactly one-half cannot be filled).

Instructions Error-estimation Task

You recall the Prediction task in which you had to predict the state of every position in the matrix ("lighted versus unlighted," "one light versus two lights," "filled versus unfilled," etc.). You probably recall how many errors your team made on that task.

Now we want you to imagine some hypothetical conditions, namely that we have a highly intelligent, insightful, systematic, careful person working on the prediction problem. Imagine further that each of these displays is plugged into the apparatus. That is, imagine that he is encountering each of the displays _for the first time_, that the display is plugged in the apparatus when he works the prediction task for the first time. If it is simpler for you, imagine that we have five identical such ideal problem-solvers and that each works on the prediction task with only one of these displays. Your task is to estimate the minimum number of errors such a person could reasonably be expected to make on each of the displays.

Another way of thinking about this task is that you are to compose a procedural rule for predicting the matrices which will yield the fewest prediction-errors across all displays. You might think of a different rule for each display, but your task is to find a single rule which, when applied to all five displays, yields the fewest errors which could be reasonably expected.

Remember, assume that your ideal problem-solver is highly intelligent, systematic, observant, and careful, but do not assume that he is unusually lucky. The performance of your teams will be compared with your individual estimates to determine (1) if the team-estimates are poorer than, equal to, or better than the _average_ of individual estimations, and (2) if the team-estimates are poorer than, equal to, or better than the performance of the _best_ individual performance. Similarly, group-performance will be compared with team and individual performances.

We have observed more than 30 teams working on this problem. The usual procedure is for team members to take turns describing the procedural rule they regard as optimal. No individual has yet identified a rule superior to our "runs-and-repetitions" rule although several persons have developed essentially the same rule:

1. Begin "in" any corner and proceed across or down the row or column and continue in the same way across adjoining rows or columns;

2. For the first hole, predict "lighted" or "unlighted" ("blocked" or "unblocked," "red" or "green") arbitrarily;
3. Predict that the next hole is in the same condition as the last one across the entire row or column;
4. In beginning the next row or column, predict that the first hole is in the same condition as its counterpart in the immediately preceding row or column;
5. If hypothesis (4) is confirmed, continue across the row or column predicting that it is a repetition of the immediately preceding row or column;
6. If hypothesis (4) is infirmed on the first hole, follow the "runs rule"--i.e., that the next hole is in the same condition as the previous hole;
7. If hypothesis (4) is confirmed on the second row (column), attempt to apply the "repetition" rule in every subsequent row (column); and
8. If hypothesis (4) is infirmed on the first or a subsequent hole, abandon the "repetition" rule and apply the "runs" rule throughout the remainder of the matrix.

Quite clearly, there is an easy way for every team and group to insure that its product is at least as good as the best of the individual solutions. All the team must do is to test the validity of the rule employed by its member who offers the lowest estimate. If his rule holds across all six displays, it produces the best answers the group has generated to that point. The more common procedure is for the team--usually in an effort to hold disagreement to a minimum and sometimes because of an uncritical conceptualization of "democratic" practices--to simply average over the individual estimates. Superior teams and groups use not only a different procedure but are also identified, in our experience, by a number of characteristic attributes. We have found, without exception this far, that superior teams are marked by a high tolerance for disagreement, the belief that conflict can be used constructively, and the acquisition of some skills for managing conflict within the group. These teams do not stop with identifying the best of their individual solutions, but continue with the question: "Can we think of an even better way to approach this problem?" And these groups typically have developed a level of cohesiveness which insures that any product is not viewed as the contribution of some individual member but rather as a product of the total group. It appears to be the case that while individual-products must be defended and actively promoted, group-products can be provisionally set aside while a still better solution is sought.

Teams and groups are limited in their effectiveness on this task, also, to the extent that they respond to one another in terms of stereotypes. That is, one person in the team may be seen as the one who is good at matrix-problems and he is referred to on the basis of that reputation. Or, a group may have established the common (or at least unchallenged) belief that matrix-tasks are better understood by men than by women, and on that basis the group may pay little or no attention to the estimates of the women members. This is another task in which performance is impaired if the gatekeeping function is not provided by someone.

Still another basis for poor performance is an apparent norm against persistence in seeking to understand another person. Most persons develop only a rudimentary procedural rule, or proceed on an intuitive basis. If asked to be specific in order that the others can understand the basis for the low estimates, the group-member may become defensively vague, or he may be persuasive in describing a rule which is good only for one or two displays. It is as if this task tests the ability of team- and group-members to confront one another with misunderstandings, lack of clear thinking, etc.

Important Dimensions of Variation

The tasks which we have described are only a sample of the tasks which might be developed using the basic matrix-apparatus. Among the variations we have explored are those described in the following sections. Each variation changes the nature of the task in a manner important enough to change the phenomena observed to emerge in problem-solving groups.

Situational Feedback

The apparatus can be arranged to provide confirmation or infirmation of every prediction (*explicit* in the case of the prediction problem, *implicit* in some of the other tasks). We sometimes refer to this as the "feedback absent." The "feedback absent" condition might be used with any of the *communication tasks*. When feedback is present, the team has the choice of abandoning their communication efforts and converting the task to *structure-induction*. When this occurs it is frequently associated with other indications that the team-members have lost confidence in their ability to communicate.

The advantage of using the feedback present condition in communication tasks is that it identifies the possibility of distrust arising from communication problems. For example, in the Split-team Communication task, persons in the receiving phase can indicate by tone of voice if not by content directly that they do not understand the messages they are receiving from the encoding team. Or, vice versa, the encoding team can express their discontent with the listening ability of the decoding team. A poorly understood message, particularly when it is associated with a prediction error by the receiver team, may lead to questioning whether the encoding team memorized the map competently or can still remember it.

With any task, changing from "feedback present" to "feedback absent" condition not only changes the difficulty of the task; it changes the task *per se*. Strategies which are plausible under "feedback present" conditions may become absurd under the other condition.

Restrictions in Attaining Situational Feedback

One version of the apparatus may allow any member of the team to have access to the prediction operations (pushing a switch, inserting a peg); another version may have only one special probe which completes the feedback circuit. With the former apparatus we are likely to observe very different leadership, control, and communication-behavior than with the latter.

When team-members disagree on either strategy or tactics with the first apparatus, they may discuss the differences but usually not for long. Any member of the team, in impatience and frustration, can pursue his own approach without obtaining the consent of fellow team-members. This independent action often is picked up by other team-members, converting the team's task into one of three or four individuals working individually. Such performance may produce excellent time-scores; at the expense of markedly increased error-scores.

Whoever picks up the special probe, in the second apparatus, becomes the leader of the group, functionally, for he determines by his behavior which of the strategies and tactics suggested by team-members actually will be carried out. He paces the team for speed. He usually determines when decisions have been reached, by acting on what he perceives as consensus (or as the best suggestion). With this apparatus, team-members rather quickly abandon communicative efforts at describing strategies and rationale and adopt much more persuasive messages. Impatience and frustration either produces a leadership confrontation, is expressed indirectly, or is lived with for the duration of the task. Coalitions may be formed. The leadership-position may be secure only so long as the occupant is demonstrably successful, a string of three or four errors bringing on a direct challenge to his leadership. In any event, the same display in the same size matrix with the same size team, produces very different team-behaviors with the two apparatuses.

Value As Simulations

It is still too early to make claims for the validity of the VOCOM games. At this point we have impressionistic evidence only as to how improvement on the VOCOM tasks transfers to performance on ostensibly different problems. Kind provides evidence that performance on one of the tasks is related to marital happiness (1968).

Participants in TDL programs provide us with much anecdotal evidence that the tasks are good simulations of everyday phenomena. Whether working with groups of married couples, family groups, or the staffs of organizations, we have observed many confrontations of the following sort: "The way you ... /did something/ ... on this problem was just like the way you act in ... /some back home/ ... situation." Indeed, it is rare that some members of a group do not make such comparison remarks during the debriefing after a task. Comments of this sort are extremely common in married-couples groups. Participants in married-couples groups also report that the new behaviors which they practice in the TDL tasks carry over to their interactions at home.

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PART III

INDIVIDUAL AND GROUP PERFORMANCE ON SELECTED VOCOM PROBLEMS

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In Part II we described an approach to communication training called Task-Directed Learning (TDL). The approach is designed to foster critical, self-reflexive inquiry concerning the relationship between various interpersonal phenomena and the solutions achieved by the participants for (external) problems of several kinds. If the participants are to function as a goal-attainment system, it is essential for them to have some basis for setting and describing their own goals. Although there are several ways in which this might be accomplished, one possibility is to provide TDL teams with objective data about the performance of others, either individuals or teams, with which the performance of TDL participants may be compared. Discrepancies between the performance of inexperienced teams, or individuals working alone, and of teams working in the TDL context provides a basis for assessing relative effectiveness and for at least preliminary goal-setting.

The purpose of this section is to provide a brief summary of team and/or individual performance on the Discovery Problem, the Prediction Problem and the Error-Estimation Problem. Some preliminary comparisons of individual and group performance are provided where appropriate data are available. One of the underlying interests in this work is in the relation between various performance criteria and complexity. Presumably, variation in the complexity of a team's external problem is a determinant of at least some of the interpersonal characteristics of a problem-solving team.

The material reported in this section is based on the performances of individuals and small groups who were assembled specifically for the purposes of collecting performance data. They were not involved in a TDL program at the time their performances were observed.

The Discovery Problem

As we have indicated, the principal objective of this project was to collect preliminary data on individual and group performance on Vocom Discovery Problems at three levels of complexity. For present purposes, complexity was defined in terms of matrix "grain." A 12 x 12 base matrix was used in the apparatus (Vocom Mark III). The lowest level of complexity was achieved by filling half of the cells resulting from superimposing a 4 x 4 matrix on the base matrix. The particular display selected was one of a large number of randomly generated "four-grain" displays which yielded a maximum of six errors upon application of the rule described in Section II (page 134 & 135). Figure One represents this display.

Intermediate complexity was achieved by a similar procedure in which a 6 x 6 matrix was superimposed on the base matrix. The aforementioned rule yielded a maximum of seventeen errors for the selected display. The highest level of complexity employed the 12 x 12 base matrix, half the cells randomly filled, which provided a maximum of sixty six errors by the decision rule. Figures Two and Three represent the "six-grain" and "twelve-grain" displays.

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X
0	0	0	0	0	0	X	X	X	X	X	X
0	0	0	0	0	0	X	X	X	X	X	X
0	0	0	0	0	0	X	X	X	X	X	X
X	X	X	X	X	X	0	0	0	0	0	0
X	X	X	X	X	X	0	0	0	0	0	0
X	X	X	X	X	X	0	0	0	0	0	0

Figure One The Vocom display of lowest complexity (four-grain used collecting performance data on the Discovery Problem.

X	X	X	X	0	0	0	0	0	0	0	0
X	X	X	X	0	0	0	0	0	0	0	0
0	0	X	X	0	0	X	X	0	0	0	0
0	0	X	X	0	0	X	X	0	0	0	0
0	0	0	0	0	0	X	X	0	0	0	0
0	0	0	0	0	0	X	X	0	0	0	0
0	0	0	0	X	X	X	X	X	X	X	X
0	0	0	0	X	X	X	X	X	X	X	X
X	X	0	0	X	X	X	X	X	X	X	X
X	X	0	0	X	X	X	X	X	X	X	X
X	X	X	X	X	X	0	0	X	X	0	0
X	X	X	X	X	X	0	0	X	X	0	0

Figure Two The Vocom display of intermediate complexity (six-grain) used for collecting performance data on the Discovery Problem.

X	O	X	O	O	X	X	X	X	X	X	O
O	X	X	O	O	X	O	O	O	X	X	X
X	X	O	O	O	O	O	X	O	O	O	X
X	O	X	X	X	X	X	O	O	O	X	O
X	O	X	X	X	X	X	O	O	O	X	O
X	O	X	O	O	X	X	O	O	O	X	X
O	O	O	O	O	O	O	O	X	X	X	O
X	X	X	O	X	O	O	X	O	X	O	O
X	X	O	X	X	X	X	O	X	O	O	O
O	X	O	X	O	O	O	X	X	O	X	X
X	X	X	X	O	O	O	X	X	O	X	O
O	O	X	O	X	X	O	O	O	O	X	X

Figure Three The Vocom display of highest complexity (twelve-grain) used for collecting performance data on the Discovery Problem.

Data were collected on a total of forty-five subjects, fifteen performing on each of the three displays. Subjects were students at the University of Oregon, all were volunteers, most were graduate students (n=43) and most were males (n=42). Average age was approximately thirty years. Each subject was shown the apparatus and instructed as follows:

> Some of the holes are blocked and some are open. Whether a hole is blocked or open may be determined by placing a peg in the hole. If the hole is blocked, the peg will stand up. If the hole is open, the peg will go down.
>
> You are to search for open holes by placing pegs in the board. An open hole will be marked with a peg which goes down. In locating open holes you should try to make as few mistakes as possible. Each mistake will be marked with a peg which stands up.

> You may stop your search at any time you choose. However, there are three things to keep in mind in making that decision: (1) you will be scored on the number of open positions you identify; (2) you will be scored on the number of errors made in the process; (3) you will be scored on the amount of time you take.
>
> Please let us know when you decide to stop.

If the subject decided to stop work before discovering all of the open positions, a record was made of his performance to that point (S-signal) and he was then instructed to continue until signalled to stop (E-signal):

> You have not yet located all of the open holes. Please continue to work until we signal you that all of the open holes have been identified.

When the full display was identified a record was made of the subject's commission errors (E-signal) and the subject was then provided with a sheet of paper on which was printed a replica of the blank 12 x 12 matrix. He was then instructed to reproduce the display he had just completed with as few errors as possible.

A word of explanation is in order regarding this part of the procedure. The data concerned with recall is of some interest as a possible measure of group cohesiveness. In the present context we are using the term to refer to the degree to which the individual members of a group participate coactively; i.e., sharing a commitment to solve the problem, actively monitoring the solutions proposed by members of the group, and in attending to the "feedback" derived from the tests performed on the apparatus itself. On the assumption of high coactivity, it would seem reasonable to expect more accurate and complete recall for the individual group members than for a group characterized by low coactivity. In the interest of pre-testing the feasibility of the operation, the individuals under observation in the present context were asked to provide the recall data. No recall "set" was provided since this would, of course, invalidate the use of such data as an indicant of coactivity. We will return to this matter in a later section concerned with comparing individual and group performance on the Discovery Problems.

Tables One, Two and Three summarize the error and time performance of individuals on the three Discovery Problems used in this study. (Pages 148, 149, 150)

Similar performance data were collected on three and four-person _ad hoc_ groups. In the present context the phrase _ad hoc_ merely refers to the fact that these groups had not had prior working experience in the specific groups formed for obtaining the performance data in question. In varying degrees, some of the subjects were acquainted with each other in other contexts; i.e., the group members were not uniformly "strangers" to one another.

Each group was acquainted with the apparatus (again, Vocom Mark III) and given the same basic instructions which were given to the individuals. Time, error and recall performance was recorded for each group. In view of the fact that these data (both individual and group) were obtained for comparative inquiry in the TDL context, no effort was made to equate individuals and groups on variables such as sex, age, educational experience, etc. The mean age for subjects working in the group setting was approximately 38 years, all were graduate students at the University of Oregon, and there were approximately the same number of males as females. Although these differences

Table One

Summary of Individual Time and Error Performance for the Discovery Problem Using a Four-grain Vocom Display

	S-Signal			E-Signal		
Subject	Commission Errors	Correct Placements	Time	Commission Errors	Time	Recall Errors
1	12	53	2:32	12	3:09	12
2	13	61	3:57	13	4:22	18
3	48	68	5:08	71	6:17	50
4	14	54	4:05	22	5:29	0
5	56	72	5:15	56	5:15	57
6	24	72	3:15	24	3:15	52
7	26	50	3:32	48	4:47	59
8	55	72	7:44	55	7:44	43
9	4	17	1:02	10	3:33	33
10	36	32	4:02	36	5:28	35
11	5	51	3:17	16	6:09	18
12	16	54	3:28	17	4:16	7
13	7	66	2:52	7	3:06	47
14	27	72	4:29	27	4:29	23
15	19	72	4:29	19	4:29	32
Median	19	61	3:57	22	4:29	33
Q	11.5	9.6	1:00	16.9	1:04	17.5

Table Two

Summary of Individual Time and Error Performance for the Discovery Problem Using a Six-grain Vocom Display

	S-Signal			E-Signal		
Subject	Commission Errors	Correct Placements	Time	Commission Errors	Time	Recall Errors
1	35	59	2:50	58	3:51	61
2	7	8	1:21	32	8:02	45
3	29	68	4:35	51	6:22	50
4	19	59	2:41	51	4:59	32
5	53	72	5:20	53	5:20	73
6	30	42	4:34	62	7:32	58
7	41	72	7:27	41	7:27	27
8	15	24	2:40	58	7:09	37
9	8	25	2:04	31	7:30	34
10	40	57	5:43	53	8:41	75
11	23	67	5:13	50	6:32	47
12	39	64	5:13	39	5:30	46
13	24	72	5:18	24	5:18	56
14	38	71	4:24	58	4:59	76
15	13	50	2:37	27	4:35	34
Median	29	59	4:39	50	6:22	47
Q	12.6	20.6	1:19	25.5	1:15	11.7

Table Three

Summary of Individual Time and Error Performance for the Discovery Problem Using a Twelve-grain Vocom Display

S-Signal				E-Signal		
Subject	Commission Errors	Correct Placements	Time	Commission Errors	Time	Recall Errors
1	42	38	4:15	71	7:47	62
2	56	52	16:07	72	22:06	64
3	24	31	2:44	71	6:21	70
4	34	39	14:18	72	28:45	62
5	16	20	1:29	72	7:12	78
6	72	72	8:52	72	8:52	67
7	31	33	1:38	72	5:22	72
8	36	37	4:20	71	7:41	64
9	21	12	4:39	71	30:17	62
10	72	72	3:29	72	3:29	70
11	30	33	4:15	72	5:56	72
12	11	14	5:54	72	15:00	72
13	54	51	18:59	72	32:55	67
14	8	11	0:51	69	5:09	71
15	72	72	8:07	72	8:07	57
Median	34	37	4:20	72	7:47	67
Q	19.6	17.7	3:12	.5	14:41	4.6

preclude a serious comparison of individual and group performance, it is of some interest to examine the data with respect to possible implications for more carefully controlled studies of group performance on this problem.

Tables Four, Five and Six (page 152,153,154) summarize the performance of the groups on the same displays used for individual subjects (Figures One, Two and Three).

Figures Four and Five graphically present the performances of individuals and groups as a function of display complexity. Tables Seven and Eight summarize the performances of individuals and groups with respect to time, error and recall. In general, statistical analyses of the differences between individuals and groups yield significance for only the S-signal condition. At the most complex display level (12-grain) the groups made significantly more correct display placements and made significantly more commission errors. In effect, the groups literally filled the matrix with pegs before signalling completion while individuals filled approximately half the matrix. The differences in time at the 12-grain level between individuals and groups is not significant which suggests a faster rate of decision-making for groups. On the other hand, the groups appeared to abandon the search for structure at the most complex display level; in effect, they often appeared to convert the task to one of merely filling holes with pegs. These observations suggest the possibility that groups differed from individuals at this level of complexity in trading-off for display completion in favor of minimizing error, while individuals more characteristically compromised completion and the avoidance of error.

Table Four

Summary of Group Time and Error Performance for the Discovery Problem Using A Four-grain Vocom Display

	S-Signal			E-Signal		
Group	Commission Errors	Correct Placement	Time	Commission Errors	Time	Individual Recall Error
1	15	72	2:30	15	2:30	72,36,18,0
2	15	72	6:57	15	6:57	0, 0, 0,24
3	15	54	4:46	16	6:30	18,44.18, -
4	15	66	8:00	15	8:30	24,18,36,40
5	24	72	5:50	24	5:50	25,38,33,40
6	31	72	2:39	31	2:39	13,32, 0,35
7	11	72	4:20	11	4:20	0, 0, 0, 0
Median	15	72	4:46	15	5:50	18
Q	10.5	4.5	1:37	.5	2:00	16

Table Five

Summary of Group Time and Error Performance for the Discovery Problem. Using a Six-grain Vocom Display

	S-Signal			E-Signal		
Group	Commission Errors	Correct Placements	Time	Commission Errors	Time	Individual Recall Errors
1	12	52	27:30	23	43:02	26,46, 7,24
2	58	72	3:45	58	3:45	78,44,47,56
3	26	72	4:35	26	4:35	28,76,69,36
4	42	72	4:29	42	4:29	63,79,82,46
5	16	40	13:00	33	18:30	42,76,38,47
6	12	14	12:30	21	18:30	8,40,14,13
7	29	72	25:32	29	25:32	12,36,30, -
Median	26	72	12:30	29	18:30	42
Q	10.0	19.5	5:54	6.7	8:11	15.0

Table Six

Summary of Group Time and Error Performance for the Discovery Problem Using a Twelve-grain Vocom Display

	S-Signal			E-Signal		
Group	Commission Errors	Correct Placements	Time	Commission Errors	Time	Individual Recall Error
1	70	72	2:10	70	2:10	63,82,73,65
2	72	72	5:55	72	5:55	76,76,66,72
3	59	62	19:55	72	20:35	56,75,63, -
4	72	72	3:30	72	3:30	77,67,74,75
5	72	72	5:06	72	5:06	79,77,56,81
6	45	42	12:45	72	14:36	62,63,71,64
7	37	41	28:56	70	29:51	72,64,71,51
Median	70	72	5:55	72	5:55	71
Q	14.5	15.5	11:29	1.0	6:34	6.5

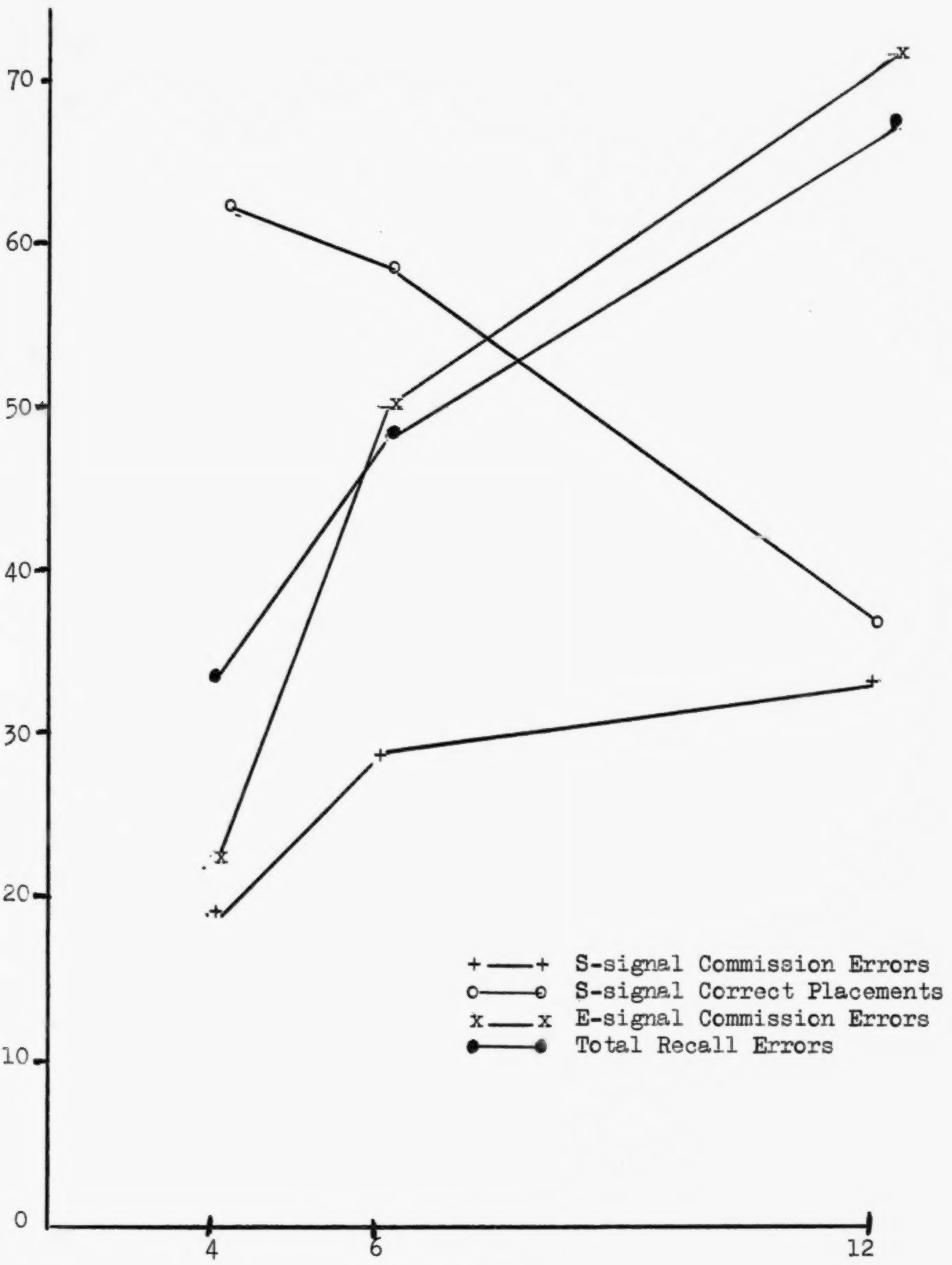
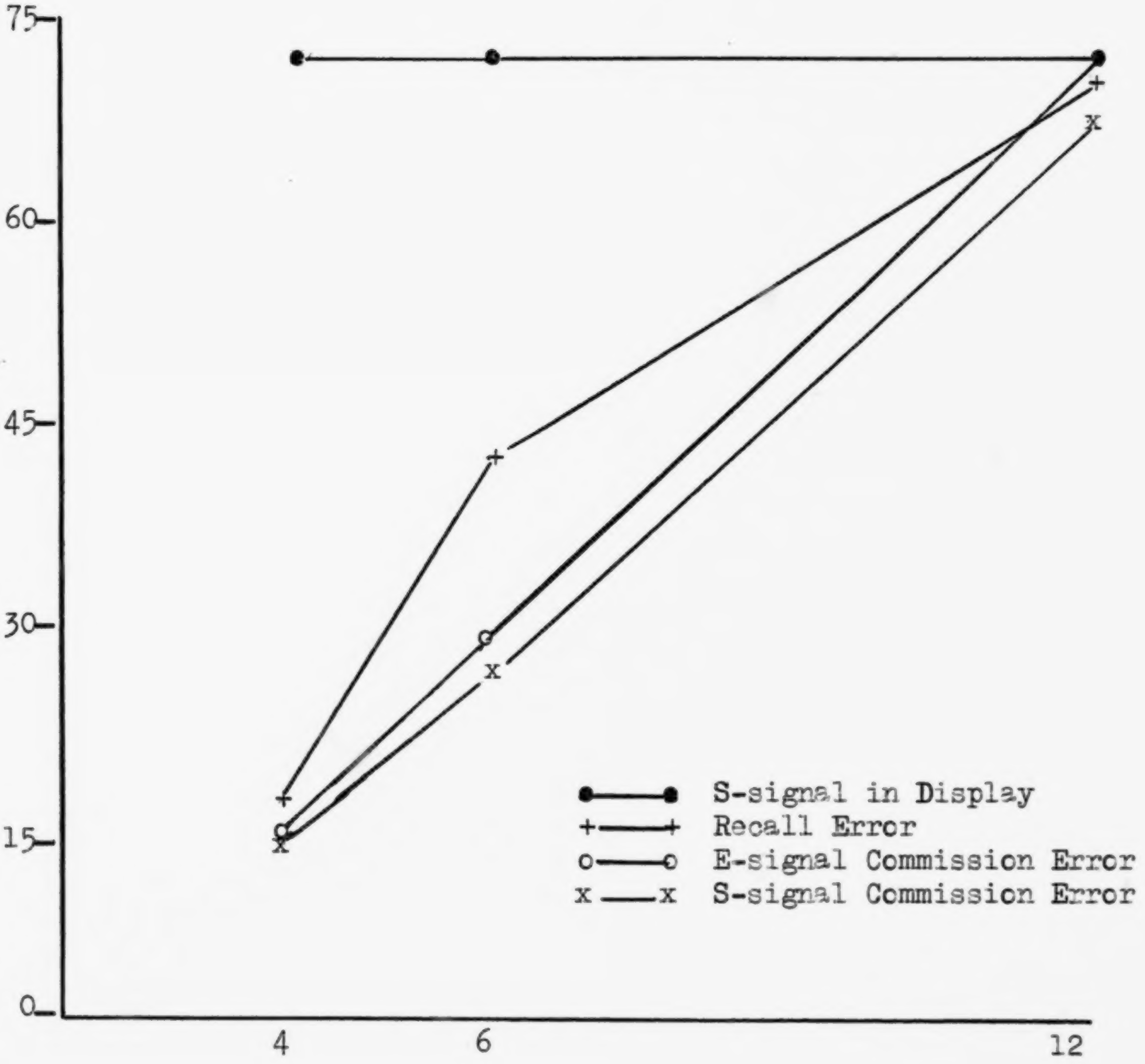


Figure Four. Median performance scores for individual subjects on the Discovery Problem at three levels of complexity (n=15 at each level).



Complexity

Figure Five. Median small group performance scores on the Discovery Problem at three complexity levels (n=7 for each level).

Table Seven

The Discovery Problem - Comparison and Statistical Analysis of Individual and Group performance (medians) At Three Levels of Display Complexity

		Complexity		
Criterion		4-grain	6-grain	12-grain
S-signal Correct Placements	Individual	61	59	*37
	Group	72	72	72
S-signal Commission Errors	Individual	19	29	*34
	Group	15	26	70
S-signal Time	Individual	3:57	*4:39	4:20
	Group	4:46	12:30	5:55
E-signal Commission Errors	Individual	22	50	72
	Group	15	29	70
E-signal Time	Individual	4:29	6:22	7:47
	Group	5:50	18:30	5:55
Total Recall Error	Individual	33	47	67
	Group	18	42	71

*Significant - Mann-Whitney U Test - .05 level of significance

Table Eight

The Discovery Problem - Summary and Statistical Analysis for Individual and Group Performance (medians) As a Function of Display Complexity

Criterion	Grain	Individual	Group
S-signal Correct Placements	4	61	72
	6	59	72
	12	37	72
S-signal Commission Errors	4	19	* 15
	6	29	26
	12	34	70
S-signal Time	4	3:57	4:46
	6	4:39	12:30
	12	4:20	5:55
E-signal Commission Errors	4	22	15
	6	* 50	* 29
	12	72	70
E-signal Time	4	4:29	5:50
	6	* 6:22	* 18:30
	12	7:47	5:55
Total Recall Error	4	33	18
	6	* 47	* 42
	12	67	71

*Kruskal-Wallis One-way Analysis of Variance - significant at .05 level. All indicated two and three-way comparisons significant except S-signal Commission Error (group), 4-grain vs 6-grain. Mann-Whitney U Test at .05 significance level for separate comparisons.

This possible difference in trade-off is further supported by the observation that the groups tended to complete the display at S-signal at all levels of complexity. It is not at all clear why groups should differ from individuals in this respect. One possibility is that groups allow the responsibility for making commission errors to be "socially distributed," thus reducing the negative effect of error, thereby decreasing the tendency to seek a means for avoiding error. Such an effect, if present, may also enhance the search for correct display positions for groups through some form of social facilitation; i.e., providing mutual encouragement for locating still another display position despite the possibility of error. The likelihood of such phenomena may be related to the complexity of the task since the groups took significantly more time than individuals at the moderate level of display complexity, and this would suggest a more cautious search for the display when some degree of structure is present.

Apart from the foregoing speculations, the most characteristic finding when comparing groups and individuals on the discovery task is the lack of statistical support for differences in performance.

When the data for either individuals or groups are examined for the effects of structure, differences are readily apparent. As Table Eight reveals, under E-signal conditions commission errors are significantly related to complexity for both indivuals and groups. The Discovery Problem may be thought of as a problem in "information retrieval" in at least two ways. The subject is required to retrieve all the pertinent items from the physical matrix and the number of commission errors is an index of his effectiveness.

When the positions of pertinent items have been revealed, the recall operations requires a retrieval of pertinent information from "memory." There is no evidence in these data that groups perform more effectively than individuals in retrieving pertinent items from the matrix. A similar finding holds for immediate recall. On the other hand, the retrieval efficiency of both individuals and groups is significantly related to complexity in both modes of retrieval.

In view of the fact that groups used in this project were ad hoc groups, these data suggest that the recall operation may provide a useful approach to the assessment of coactivity in at least the sense that recall errors can be markedly reduced. It remains for future investigation to study the relationship between coactivity and the level of recall error.

It was pointed out earlier that the data for individual and group performance were collected for use as referent data in the TDL context. The foregoing discussion must be considered as highly tentative in view of the rather gross differences between the individual subjects and those used in the group setting. Under these conditions, any effort to account for the differences would be based on speculation not warranted by the quality of the data at hand. Perhaps the most useful finding, and the least problematic, is the relation between problem-complexity and both individual and group performance. The data would appear to warrant more careful investigation of difference between individual and group performance as a function of complexity.

The Prediction Problem

One of the essential differences between the Prediction Problem and the Discovery Problem is in the amount and nature of the information gained by the subject in the course of his decision-making. While the Discovery Problem provides information for each matrix position tested, the subject's "prediction" of non-display is not tested since he is instructed to place pegs only in the display areas. In the case of the Prediction Problem, every matrix position is tested and the subject is free to change his predictions as the test information is accumulated.

The basic purpose of this project was to gather data on individual performance on the Prediction Problem for assessment purposes in communication training programs (TDL). Again, complexity was defined in terms of "grain" and the base matrix was 12 x 12. Four, six and twelve-grain problems were used. The four-grain and twelve-grain displays were the same as those used for the Discovery Problem (See Figures One and Three). Figure six is a representation of the six-grain display used in this project. This display yields a maximum of eighteen errors by the rule referred to on page 134-5.

X	X	X	X	X	X	O	O	O	O	O	O
X	X	X	X	X	X	O	O	O	O	O	O
O	O	O	O	O	O	X	X	O	O	X	X
O	O	O	O	O	O	X	X	O	O	X	X
X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X
O	O	X	X	O	O	O	O	X	X	X	X
O	O	X	X	O	O	O	O	X	X	X	X
O	O	X	X	O	O	X	X	X	X	O	O
O	O	X	X	O	O	X	X	X	X	O	O
O	O	X	X	X	X	O	O	O	O	X	X
O	O	X	X	X	X	O	O	O	O	X	X

Figure Six The six-grain display used in conjunction with the Prediction Problem.

Performance data were collected on a total of forty-five undergraduate, volunteer subjects. Fifteen subjects were used to obtain the data for each display. Each subject was shown the apparatus (Vocom Mark III) and instructed in essentially the same manner as for the Discovery Problem. The important difference concerned the use of color-coded pegs in registering the prediction of open or closed positions. In the present operations the subjects were required to continue work until a prediction had been made for each matrix position. Performance was timed to the nearest fifteen seconds. Upon completion of the matrix predictions, the subject was again given a paper replica of the matrix and asked to reproduce the arrangement of open and closed holes with as few errors as possible. Tables Nine, Ten and Eleven present the relevant performance measures for this problem.

Statistical analysis* reveals significant differences at the .05 level among the medians for both prediction error and reproduction of the display (recall). All individual comparisons were significant (.05 level) for the criterion of prediction-error; however, for recall the differences were significant between the 4-grain and both the 6-grain and 12-grain displays. The difference between 6-grain and 12-grain was not significant. It will be recalled that the recall differences for the Discovery Problem were uniformly significant for all display comparisons both for individuals and for groups. Several factors may account for the relatively high recall error on the 6-grain display under the prediction operations. First, the 6-grain displays were not the same for the Discovery and the Prediction Problems. The 6-grain display used for the Prediction Problem may be inherently more difficult to recall than that used for the Discovery Problem. There were also noticeable differences in the subjects used in the two problems. There is also the possibility that the recall operation is differentially affected by the essential differences between the two problems; i.e., the Discovery Problem may provide a somewhat stronger "display set" in that the search is for display positions while the Prediction Problem involves aligning predictions with both display and non-display positions. If the latter factor is even partially responsible for the observed differences in recall performance, it must also be argued that the effect emerges differentially as a function of structure, specifically at the 6-grain level. Presumably, the lowest level of complexity used in these studies presents relatively low recall difficulty for either the discovery or prediction operations, while a 12-grain display appears to present a distinct recall "overload" in that performance under both conditions differs little from what would be expected by chance.

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*Kruskal-Wallis One-way Analysis of Variance for over-all tests and Man-Whitney U Test for individual comparisons.

It is of some interest to compare the performances of individuals and groups on the Discovery Problem with those of individuals on the Prediction Problem. Table Twelve provides a summary of total error performance for the conditions involved. For purposes of the comparison, it must be assumed that when a subject (or group) places a peg in the matrix (under the discovery conditions) the act is logically equivalent to a prediction of "display" while failure to place a peg in the matrix is the equivalent of the prediction "non-display." Given this assumption, total error for S-signal performance under the discovery condition is the sum of the ommission and commission errors and is equivalent to the sum of the prediction errors for the prediction condition. Clearly, this assumption is open to considerable doubt since a subject may stop work under the discovery conditions for a number of reasons and therefore the areas of the matrix which have not been tested may or may not be regarded as non-display predictions.

Nevertheless, it is of interest to note the disparity in performance between the individuals working on the discovery problems and those working on the prediction problems. The discovery problem requires the subject to place a peg (thus registering a display prediction) in order to determine the state of any particular display position. Under the conditions of the prediction problem, information may be gained about the state of any matrix position without necessarily earning an error since the subject is free to register his prediction of either display or non-display in advance of placing the peg. To the extent that there is some structure holding among the states of the matrix positions, there is the possibility of aligning predictions with actual states of the matrix thereby achieving the desired information while minimizing the likelihood of error. As Table Fifteen indicates, when there is no structure (12-grain display) the error scores for the two tasks are equivalent and do not differ from chance.

It may also be noted that group performance under the discovery conditions corresponds reasonably well with individual performance under the prediction conditions. Although this may suggest that groups are operating more effectively than individuals on the Discovery Problem, it is also the case

Table Nine

Individual Time and Error Performance for the Prediction Problem Using a Four-grain Vocom Display.

Subject	Prediction Errors	Time	Recall Errors
1	9	7'30"	0
2	21	6'30"	63
3	18	11'45"	36
4	15	6'30"	41
5	15	7'00"	3
6	10	9'00"	11
7	10	7'00"	69
8	29	7'00"	16
9	23	9'00"	84
10	9	8'00"	50
11	11	7'30"	114
12	23	10'00"	28
13	8	6"00"	0
14	10	8'00"	6
15	13	10'00"	18
Mdn	13	7'30"	28
Q	4.5	1'04"	23.88

Table Ten

Individual Time and Error Performance for the Prediction Problem Using a Six-grain Vocom Display.

Subject	Prediction Errors	Time	Recall Errors
1	37	11'00"	76
2	30	7'30"	58
3	36	7'00"	84
4	41	7'00"	66
5	28	9'00"	92
6	28	8'00"	48
7	47	8'00"	54
8	22	8'30"	55
9	33	16'00"	67
10	31	9'30"	66
11	21	14'00"	48
12	24	11'30"	108
13	35	11'00"	53
14	22	15'30"	94
15	30	11'00"	-
Mdn	31	9'30"	66
Q	5.88	1'38"	13.25

Table Eleven

Individual Time and Error Performance for the Prediction Problem Using a Twelve-grain Vocom Display.

Subject	Prediction Errors	Time	Recall Errors
1	82	9'00"	67
2	76	9'00"	72
3	68	12'30"	69
4	72	11'00"	68
5	71	13'00"	66
6	76	10'00"	69
7	67	13'30"	71
8	74	20'30"	65
9	70	10'00"	75
10	76	12'00"	77
11	70	7'00"	75
12	78	16'30"	75
13	66	33'30"	73
14	69	58'00"	55
15	76	27'30"	65
Mdn	72	12'30"	69
Q	3.42	2'10"	3.86

Table Twelve

Summary of Median Individual and Group Performances (total error) On the Discovery and the Prediction Problems At Three Levels of Complexity

	Discovery Problem				Prediction Problem
	Individual		Group		Individual
Display Grain	S-signal	E-signal	S-signal	E-signal	
4	30	22	15	15	13
6	42	50	26	29	31
12	69	72	70	72	72

that the discovery condition provides additional information to the subjects over that provided in the prediction condition; that is, the completion phase of the discovery operations is initiated with a message from the experimenter to the effect that some of the display positions have not yet been identified. The data may suggest that groups are better able to employ this information than individuals to reduce errors. In any case, the data are merely suggestive and in present form not amenable to meaningful statistical analysis. The matter is mentioned in the present context largely by way of indicating some potentially fruitful areas of experimental inquiry.

The remaining point of interest in connection with the prediction operations concerns the ability of the subjects to reproduce the display in question. An informal comparison of the recall performance under both discovery and prediction conditions is presented in Figure Seven. Although the total prediction errors appears to be markedly lower for the Prediction Problem, recall errors are considerably higher than for the Discovery Problem at the six-grain level of complexity. Again, several factors may account for this apparent loss in recall efficacy under the prediction conditions. Presumably, the four-grain complexity level is sufficiently ordered to present no particular recall difficulty under either condition. The twelve-grain level represents a considerable information overload with respect to recall and both conditions are associated with performance levels little different from chance. The apparent difference at the six-grain level may be due to the differences in the form and amount of information gained by the subjects under the two conditions. The Prediction Problem involves "reading"

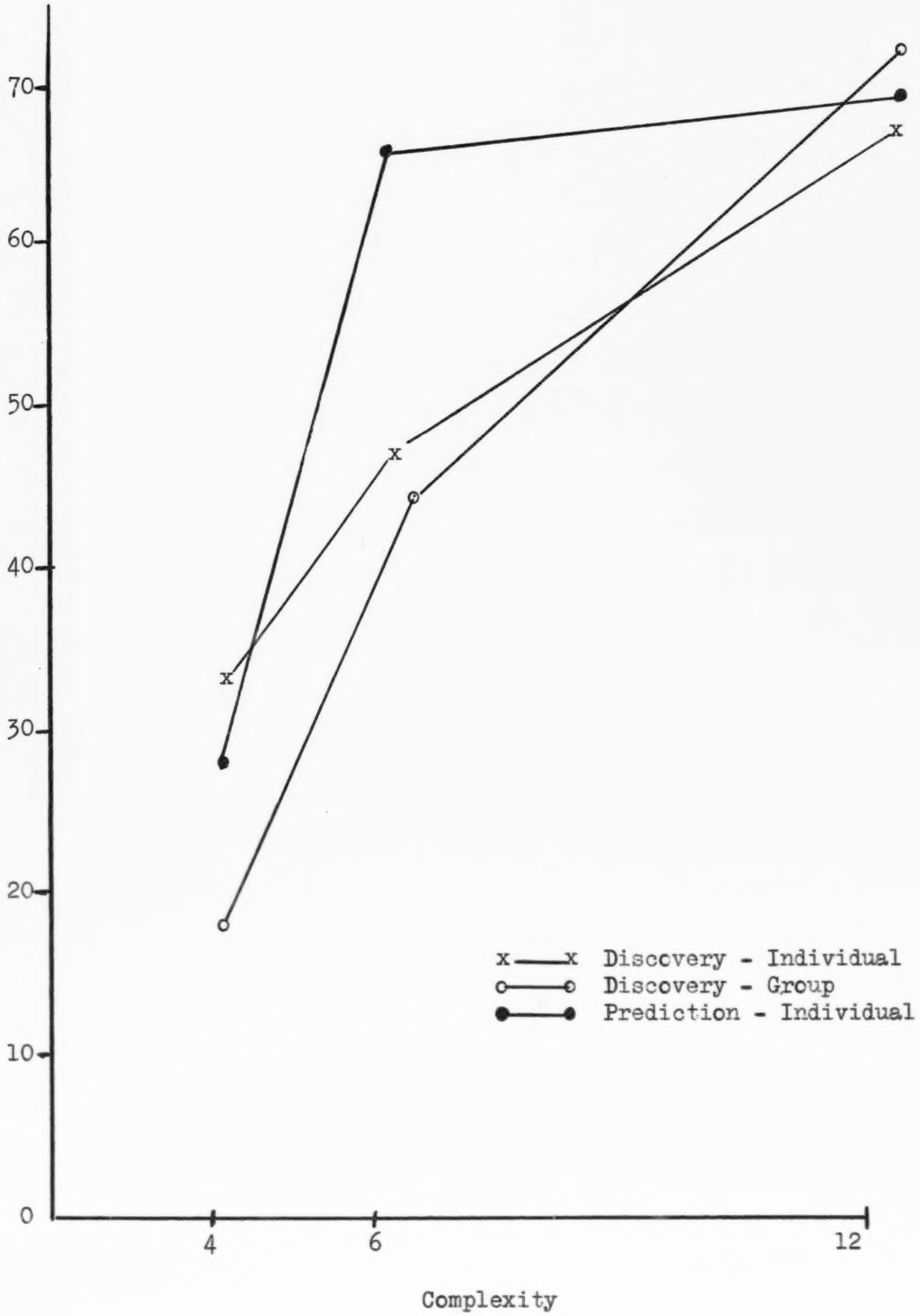

Figure Seven. A comparison of immediate recall medians for four, six and twelve-grain displays for the Discovery Problem (individuals and groups) and for the Prediction Problem (individuals).

the display with all matrix positions filled with either red or white pegs. The display is recorded in terms of peg elevations. On the other hand, only a single peg-color is employed in the Discovery Problem and the display is again revealed in elevation differences. Thus, in neither case is the full and complete display presented to the subject without possible interfering effects of irrelevant information. On the other hand, and as we have pointed out earlier, the Discovery Problem directs the subject to "seek the pattern" while in the Prediction Problem the subject is oriented to reducing prediction errors with respect to both display and non-display areas. It seems possible that the discovery operations create a different perceptual set and one which would be expected to enhance recall ability. Again, the apparent differences need more carefully controlled investigation.

The Estimation of Complexity

Although a considerable amount of both theoretical and experimental attention has been given the concept of preference for varying amount of complexity (Berlyne, Dorfman, and Vitz), it appears that little attention has been given to the estimation of complexity. Among the approaches that might be employed in studying this matter it may be useful to build on the relation between complexity and prediction error. From this point of view, an expressed preference for a particular complexity level may be construed as preference for confirmative (or infirmative) information since the number of correct predictions (and errors) is clearly related to complexity level. The data from both the Discovery Problem and the Prediction Problem clearly support this relationship. It seems plausible to entertain both complexity preference and estimation of complexity as among the determinants of problem-solving behavior as well as the communicative process. Thus, for example, a person characterized by a preference for high complexity confronted with a low complexity problem may perform quite differently from others in terms of time and/or error score through mere boredom. Similarly, a person showing preference for low complexity may withdraw from a high complexity problem (e.g., a six-grain Discovery Problem under S-signal conditions) sooner than one showing preference for higher complexity. This person would, of course, be less "well-informed" in the role of a consultant to another. Another possibility involves team-functioning in, for example, the TDL context. It is quite conceivable that a team of individuals having a preference for high complexity may appear to be far less "conservative" in their approach to a relatively complex problem than other teams.

This line of conjecture assumes, of course, that the complexity level for a particular display "emerges" as a product of sequential decision making as in the discovery and prediction operations. In this case, the estimation of complexity may be regarded as an inductive guess about the possibility of cumulative error as the work proceeds. Alternatively, the estimation of complexity may be viewed in the context of "pattern recognition" in at least the sense that the entire display is presented for the subject's scrutiny and his task is to estimate the number of errors he might make if he were to "process" the same display sequentially. In either case, estimated complexity and preference for complexity may be important determinants of the decision to become engaged in problem-solving, the nature of problem-solving behavior employed and the nature of communicative relationships which may occur.

In brief, there appears to be a sufficient conjectural basis for undertaking at least a preliminary investigation of the ability to estimate complexity when complexity is defined in terms of prediction error. Accordingly, this section is given to a report of preliminary findings with regard to complexity estimation.

Complexity Estimation - Procedure

A total of eighty-seven Vocom displays were generated randomly on a 12 X 12 base matrix and on five superimposed matrices to achieve six different display grains. Table Thirteen summarizes the grain levels, number of displays at each level and the number of filled matrix "units" at each level. At each level except one-grain and two-grain approximately the same number of displays were generated for each of the alternative numbers of filled squares. For example, three-grain displays were composed of either four or five filled matrix units, and ten of each were generated. The eighty-seven displays were reproduced on 8½" X 11" sheets of paper containing a 12 X 12 matrix approximately six inches on a side. Five different random orders of the full set of displays were then arranged in loose-leaf notebooks for the use of subjects in estimating prediction errors.

Subjects were prepared for the estimation task by first demonstrating the Vocom apparatus (Mark I) and allowing each subject to make approximately thirty decisions on one or the other of two "training" displays. On the

Table Thirteen

Matrix size, Number of Displays and Range of Filled Squares for Displays Used in Complexity Estimation Study.

Matrix	Number of Displays	Range of filled units
1 X 1	1	0
2 X 2	6	2
3 X 3	20	4-5
4 X 4	20	7-8-9
6 X 6	20	16 thru 20
12 X 12	20	64 thru 80

assumption that the training operations might provide an estimation bias, two different displays were used; one was a two-grain display, the other was six-grain. Subjects were undergraduage college students, twenty six males and twenty three females. They were randomly assigned to one of the two training displays and instructed as follows:

> We first want you to become acquainted with this apparatus and some procedures for making decisions. These phone-jacks have been wired in such a way that when you insert this probe it will turn on either the green light here at the bottom or both the green light and the red light at the top. In order to find out whether a particular jack turns on only one or both lights you will have to press one of these switches. Use the one on the left marked 'one light' if you think the jack you are testing is a one-light jack. If you think it is a two-light jack use the switch on the right marked 'two lights.'
>
> Your task is to guess which of the jacks are one-light jacks and which are the two-light jacks, and to guess correctly as often as possible. There is no time limit. Your guessing errors will automatically register on this recorder. In order to remember the one and two-light positions you have located, mark each two-light position with a red peg and mark each one-light position with a yellow peg.
>
> In review, your task is as follows:
>
> 1. Choose any jack you wish and insert this probe.
> 2. Press the one-light switch if you think the jack will turn on only one light; press the two-light switch if you think the jack will turn on both lights.
> 3. If the jack actually turns on only one light mark that position with a yellow peg; if it actually turns on both lights mark that position with a red peg.
> 4. Continue to select, guess and mark until you have tested all the jacks. You may proceed in any order you choose, and there is no time limit.
> 5. Remember, your basic task is to guess where the one-light and two-light positions are and to make as few mistakes as possible.

After the subject had made the required number of predictions, he was taken to a small room, provided with a book of displays and answer sheet. Instructions were as follows:

> In your work on the apparatus you saw a small portion of a particular arrangement of one and two-light positions, and you made several prediction errors in the process.
>
> In this book you will find some diagrams of other arrangements. The blackened circles represent two-light positions. We want you to estimate the total number of errors you might have made for each arrangement had it been in the apparatus. In other words, in making your estimates assume you are working on the apparatus with the same procedural instructions as before.
>
> Remember, you are to estimate the number of prediction errors for the complete arrangement in each case. Start with the first arrangement in the book and continue in order until you have made an estimate for each arrangement. Record your estimates on this sheet. There is no time limit.

Median error estimates were calculated for each subject for each grain level represented in the book of displays. A median of the median estimates was then calculated. Figure Eight is a graphic representation of the median estimates for the two groups of subjects. The curve representing "actual" complexity was derived from an application of the "runs and repetitions" rule described earlier (See page 134-5). This curve closely coincides with expected mean performance by chance for a subject assumed to know the grain of the display.

Figure Eight also depicts the actual median error scores for the individual subjects working on selected four-,six-, and twelve-grain displays under the prediction operations (See Prediction Problem). Although the physical apparatus and prediction operations were not the same for the prediction and estimation subjects, it seems reasonable to assume that no important performance differences are associated with the physical differences in apparatus and operations. Table Fourteen summarizes the relevant values.

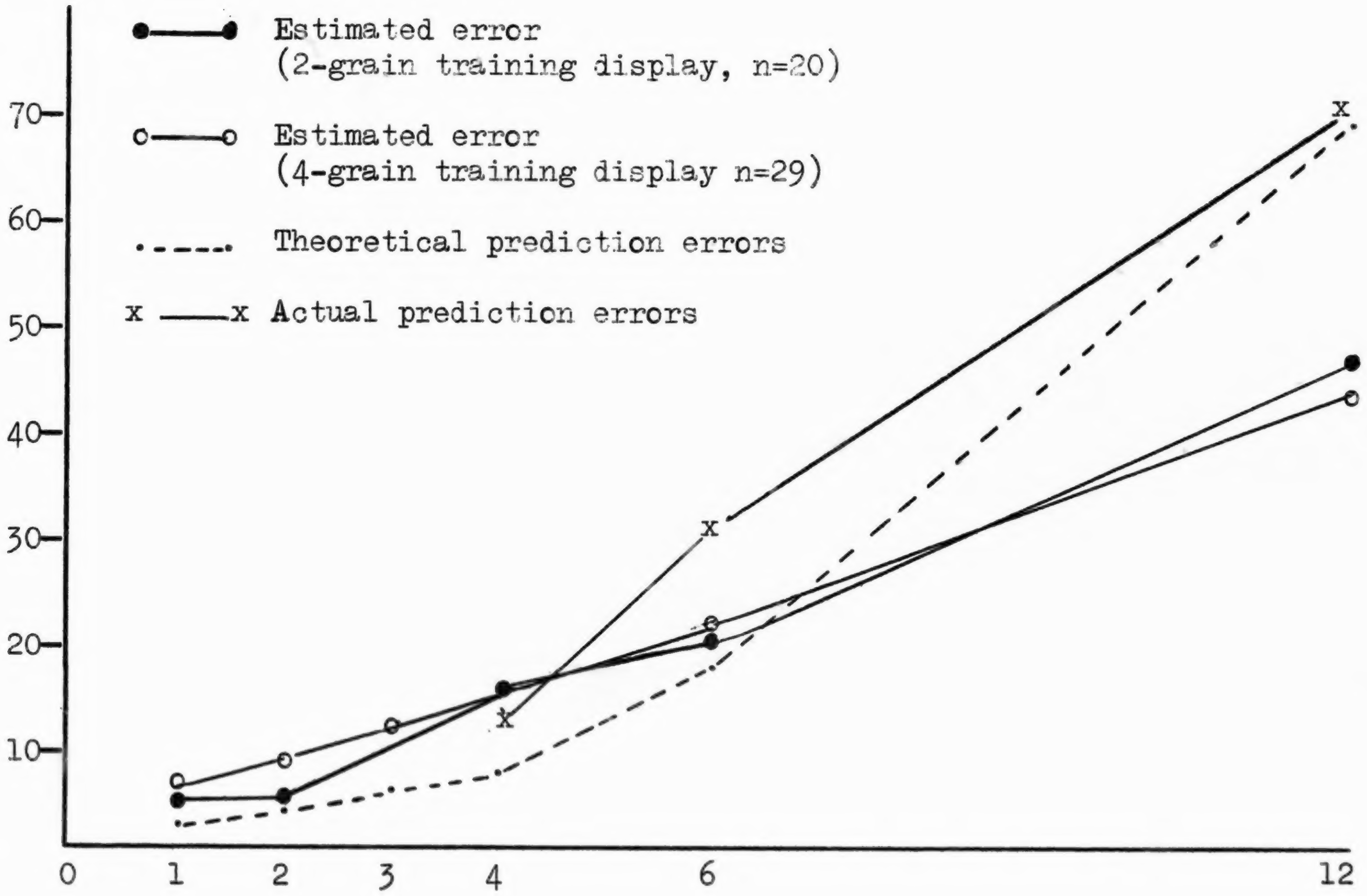

Figure Eight. A comparison of theoretical, estimated and actual prediction errors associated with increasing levels of complexity. The plotted points are median values.

Table Fourteen

A Comparison of Theoretical, Estimated and Actual Prediction Error for Vocom Displays of Differing Complexity (Medians).

		Prediction Error		
Grain*	Theoretical	Estimated (Gp I)	Estimated (Gp.II)	Actual
1	1	3	5	--
2	2	3	8	--
3	5	9	12.5	--
4	8	16	16	13
6	19	22.5	25	31
12	72	51.5	47.5	72

*The theoretical and estimated errors are based on one display for one-grain, six displays for two-grain and twenty displays for the remaining grain levels.

The curves for theoretical, estimated and actual prediction errors when compared informally reveal two particularly interesting characteristics. First, the curve of estimated error is distinctly linear and characterized by a tendency toward over-estimation when some level of structure is involved (one-grain through six-grain) and by marked under-estimation at the twelve-grain level where the structural effect of grain is absent. The actual prediction errors made by subjects given the prediction probelm (n=15 for one display at the four, six and twelve grain level) again show a distinctly linear tendency and at a higher level of error than the theoretical curve (except for the twelve-grain level where there is no difference). In brief, when some degree of structure is present, both error-estimation and actual errors tend to be higher than the theorized optimal performance. When there is no grain structure (twelve-grain), actual performance coincides with theoretical expectation while estimated error is markedly below this point. These comparisons are, of course, incidental to the present interests in accumulating performance data for use in the TDL context. Nevertheless, the present informal comparisons invite a more careful examination of complexity preference in relation to the estimation of complexity, the relation between complexity preference and prediction error, and the influence of these factors on communicative events.

Statistical analyses of the differences in error estimation as a function of training display differences (high and low complexity displays) yielded a statistically significant difference at only the two-grain level. The group trained on the more complex display tended to estimate significantly more errors at this very low complexity level. Table Seventeen suggests the possibility of a similar effect at the one and three-grain levels. However, the effect seems not to be pronounced and for purposes of providing comparative data for participants in a TDL program, it would appear that the data from the two groups may be combined.

Alternative Approaches to Complexity

In the material presented thus far complexity has been defined in terms of grain (the size of the matrix superimposed on a specified base matrix) when the number of filled cells is held constant or nearly so. For experimental purposes as well as TDL communication training there is need for alternate forms of Vocom displays for which the complexity levels may be objectively specified. The approach to be described briefly in this section is based on the use of closed figures, or "tracks." Three figures were employed in the investigation each of which consisted of twenty positions so arranged that a line drawn through the positions would yield a continuous, closed figure without cross-overs or doubling. Figures Nine, Ten and Eleven represent the tracks employed in investigating an alternate approach to developing an ordered set of displays.

The relative complexity for each figure was determined as shown in Figures Nine, Ten and Eleven and Tables Fifteen, Sixteen and Seventeen. In brief, from an assumed and arbitrary starting point, each point on the track was considered to be the center of a three by three decision environment. Each correct determination of the next position in the sequence was assumed

Table Fifteen

The Number and Frequency of Different Decision Environments Yielded by Sequential Search for Track Number One (See Figure Twelve).

Environment Number	f	p	-p $\log_2$ p
1	1	.050	.2161
2	1	.050	.2161
3	1	.050	.2161
4	1	.050	.2161
5	1	.050	.2161
6	10	.500	.5000
7	1	.050	.2161
8	1	.050	.2161
9	1	.050	.2161
10	1	.050	.2161
11	1	.050	.2161
	20	1.000	2.6610

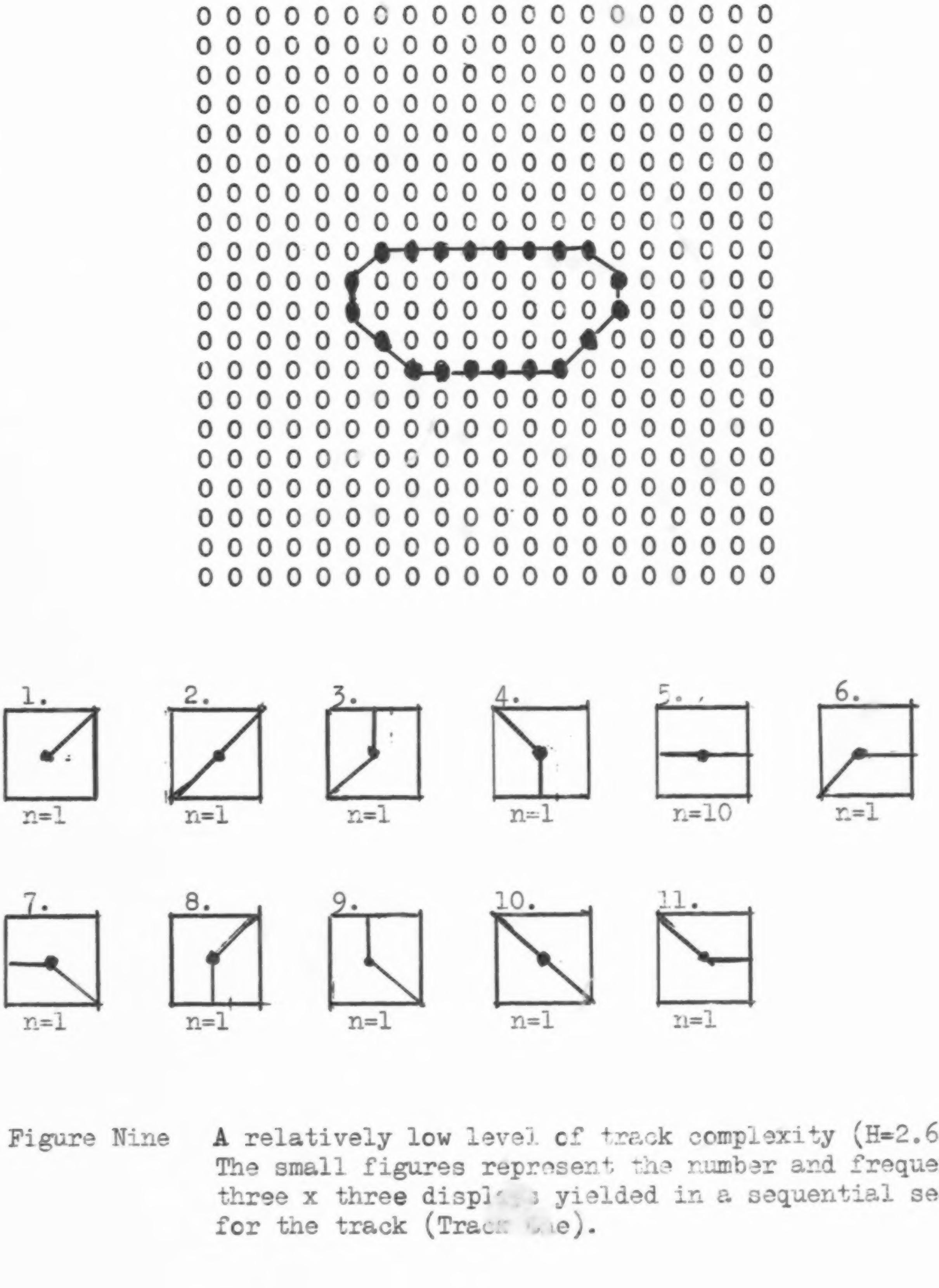
1.
n=1
2.
n=1
3.
n=1
4.
n=1
5.
n=10
6.
n=1
7.
n=1
8.
n=1
9.
n=1
10.
n=1
11.
n=1

Figure Nine A relatively low level of track complexity (H=2.66 bits). The small figures represent the number and frequency of three x three displays yielded in a sequential search for the track (Track One).

Table Sixteen

The Number and Frequency of Different Decision Environments Yielded by Sequential Search for Track Number Two (See Figure Thirteen).

Environment Number	f	p	$-p \log_2 p$
1	1	.050	.2161
2	3	.150	.4105
3	1	.050	.2161
4	2	.100	.3322
5	1	.050	.2161
6	5	.250	.5000
7	2	.100	.3322
8	1	.050	.2161
9	2	.100	.3322
10	1	.050	.2161
11	1	.050	.2161
	20	1.000	3.2037

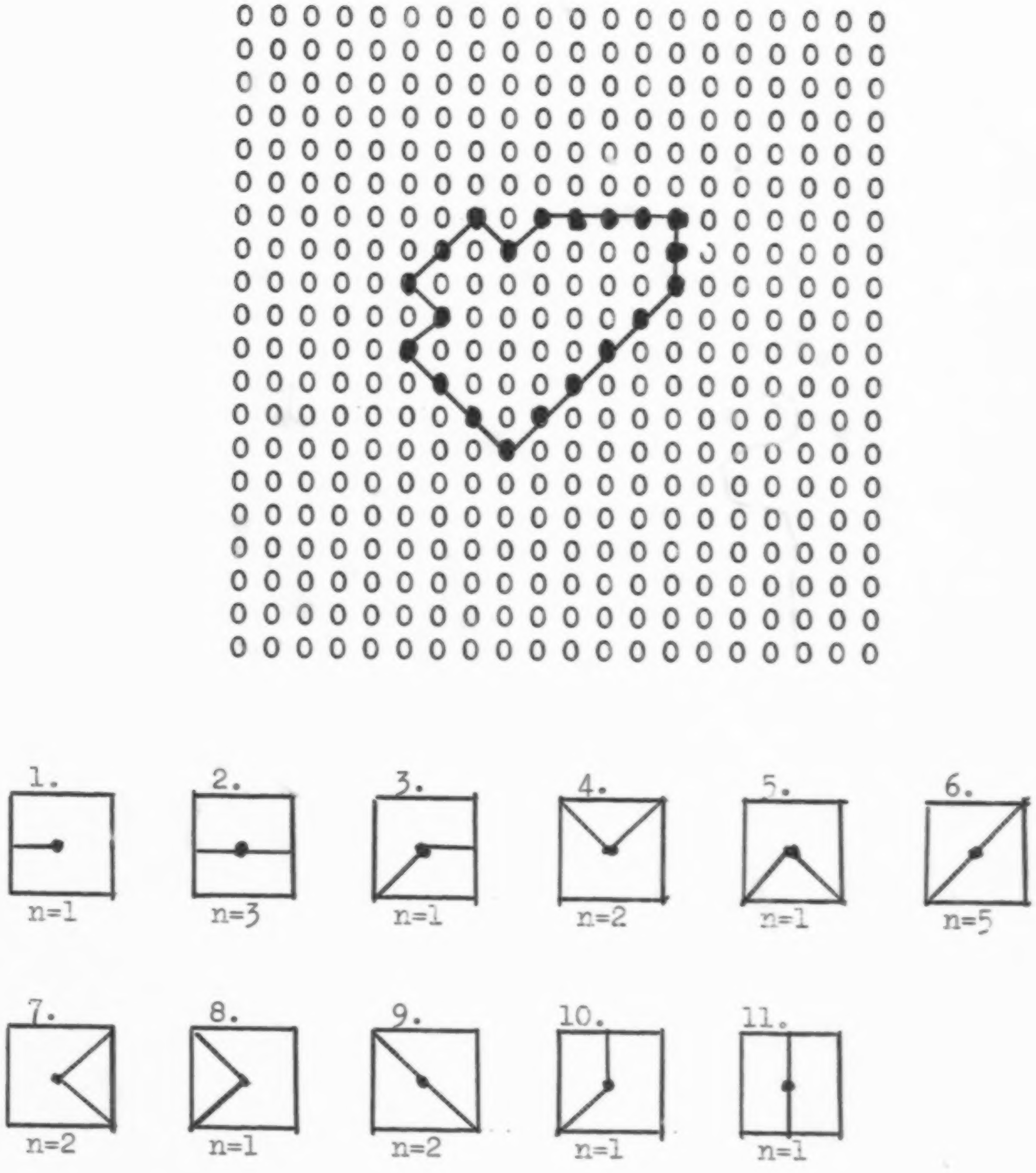
1.
n=1
2.
n=3
3.
n=1
4.
n=2
5.
n=1
6.
n=5
7.
n=2
8.
n=1
9.
n=2
10.
n=1
11.
n=1

Figure Ten A moderate level of track complexity (H=3.20 bits). The small figures represent the number and frequency of three x three displays yielded in a sequential search for the track (Track Two).

Table Seventeen

The Number and Frequency of Different Decision Environments Yielded by Sequential Search for Track Number Three (See Figure Fourteen).

Environment N Number	f	p	$-p \log_2 p$
1	1	.050	.2161
2	1	.050	.2161
3	2	.100	.3322
4	1	.050	.2161
5	1	.050	.2161
6	2	.100	.3322
7	2	.100	.3322
8	2	.100	.3322
9	2	.100	.3322
10	1	.050	.2161
11	2	.100	.3322
12	1	.050	.2161
13	1	.050	.2161
14	1	.050	.2161
	20	1.000	3.7220

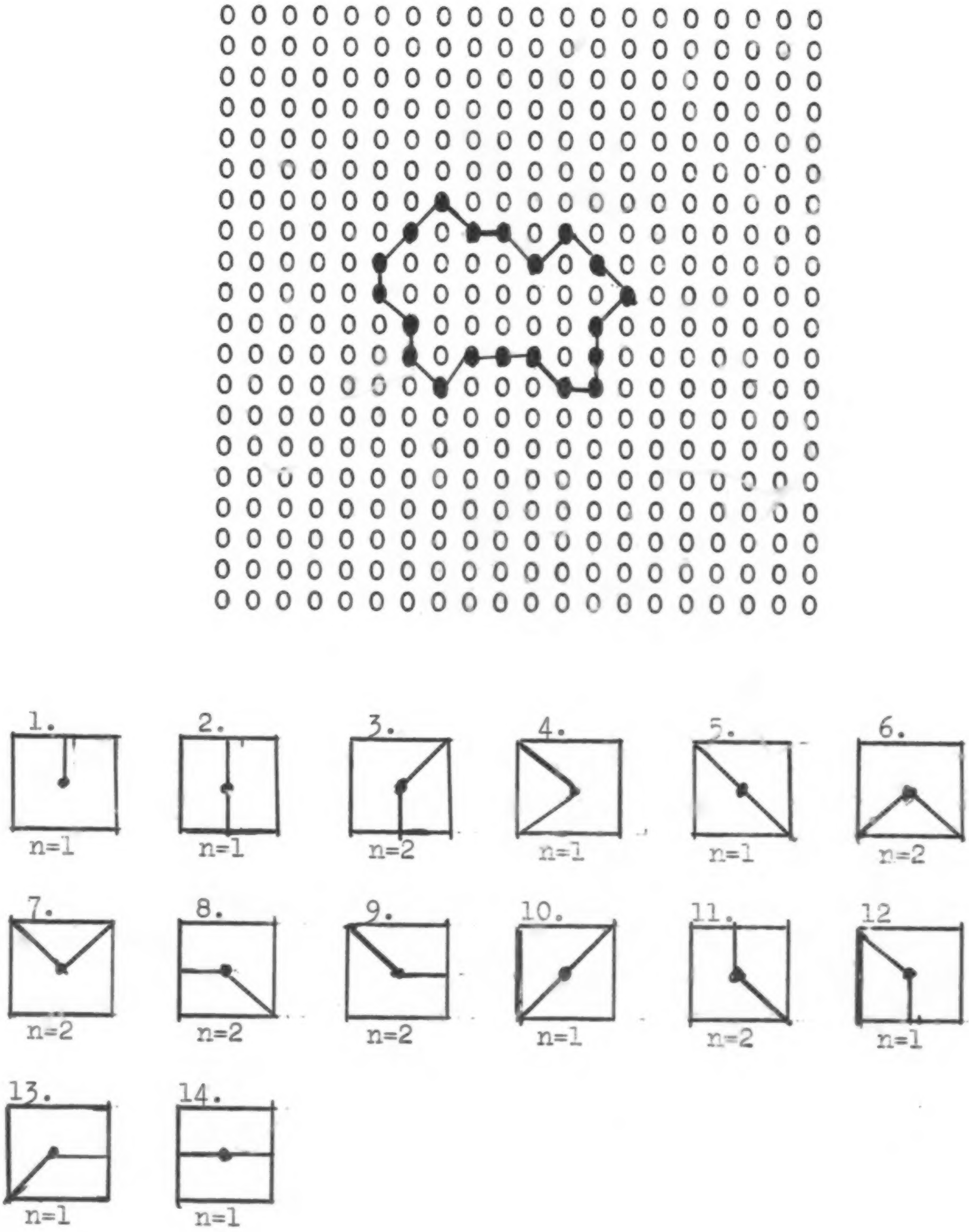
1.
n=1
2.
n=1
3.
n=2
4.
n=1
5.
n=1
6.
n=2
7.
n=2
8.
n=2
9.
n=2
10.
n=1
11.
n=2
12
n=1
13.
n=1
14.
n=1

Figure Eleven A relatively high level of track complexity (H=3.72 bits). The small figures represent the number and frequency of three x three displays yielded in a sequential search for the track (Track Three).

to yield a matrix (3 X 3) in which three cells are always filled (except for the first matrix which yields two filled cells) including the center cell. Relative complexity was assumed to be a function of the number of different three by three displays which would be yielded by sequential decision-making, and their relative frequencies of occurrence. Thus, figures having relatively long, straight lines, small numbers of angular changes, and a small number of different angles would be relatively low in complexity. A large equilateral triangle or a large square would represent this situation.

In effect, each track was considered to be composed of twenty signals some of which were repetitious, thus affecting the relative frequencies of occurrence. Complexity was then defined as $\sum -p \log_2 p$. The figures shown had complexity values of 2.66, 3.20 and 3.72 bits respectively. The figures were arranged in the Vocom apparatus (Mark I) and fifteen undergraduates college students were run as individual subjects on each figure. In each case a starting point was indicated and the subjects were instructed as follows:

> Discovery Instructions
>
> Some of the phone jacks on this panel will turn on this light and others will not. In order to find out whether a particular jack will turn on the light you will have to insert this probe and press this switch.
>
> Now, starting with this red peg we have arranged a (sequence) of jacks each of which will turn on the light. We can't tell you what the sequence looks like, but we can tell you that it is continuous, that is, there are no breaks or interruptions in it.
>
> We would like you to locate the (sequence) by using this probe and switch. For each position selected that turns on the light mark it with a red peg from this box. Any positions selected that do not turn on the light mark with a yellow peg from this box. Continue your search until you think you have found the complete sequence and then tell us.

> Work as quickly as you can and with as few errors as possible. You will be scored for both time and error.
>
> Incidentally, your performance on this problem is to help assess the equipment and procedures, it is not a test of your abilities. When you have finished we will be happy to discuss our research interests with you.
>
> If you have any questions on procedure please ask them now as I cannot communicate with you while you are actually performing the task.

When the subject had finished the problem he was given a representation of the matrix and asked to reproduce the track he had just completed. The following instructions were used:

> Now we're ready for the last part of the task. We would like you to reproduce the sequence you have just completed from memory.
>
> This sheet of paper contains 400 circles to represent the phone jacks on the board. You can black out the circles individually to indicate the phone jacks that turned on the light when the switch was pushed as I have done here to represent the same starting position you had on the board.
>
> Try to reproduce the sequence as accurately as you can. There is no time limit.

Tables Eighteen, Nineteen and Twenty present the time, error and recall* performance for fifteen subjects each at three levels of track complexity. Figure Twelve provides a graphic representation of the relation between prediction error and track complexity. Inspection of the data reveals a close, positive relation between complexity and decision error. The data were analyzed by the Kruskal-Wallis One-way Analysis of Variance which yielded significance at the .05 level. Mann-Whitney U tests were used to assess individual track performances. All tests were significant at the .05 level.

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*Recall was defined in terms of the number of track "hits" without regard to the number of attempts.

Table Eighteen

Time, Error and Recall Data for Fifteen Subjects Engaged in Sequential Decision-Making for Track One (H=2.66 bits)

Subject	Errors	Time In Seconds	Track Recall
1	17	225	.91
2	23	319	.35
3	24	418	.35
4	24	437	1.00
5	25	473	.40
6	12	213	.30
7	14	197	.80
8	22	450	.40
9	15	208	.50
10	20	283	.60
11	12	349	1.00
12	17	239	.40
13	25	304	.25
14	9	214	1.00
15	21	228	.69
Median	20	283	.50
Q	4.87	76.25	.24

Time vs Error - Rho=.72 (significant at .05 level)

Table Nineteen

Time, Error and Recall Data for Fifteen Subjects Engaged in Sequential Decision-Making for Track Two (H=3.20 bits)

Subject	Errors	Time In Seconds	Track Recall
1	34	710	.81
2	28	436	.29
3	28	---*	.50
4	32	602	.55
5	29	454	.35
6	29	642	.45
7	38	365	.15
8	26	256	.85
9	29	377	.18
10	31	288	.20
11	37	691	.60
12	32	425	.40
13	38	602	.60
14	31	332	.55
15	31	---*	.33
Median	31	454	.45
Q	2.12	146	.29

Time vs Error - Rho=.39 (significant at .10 level)
*Data missing due to equipment malfunction.

Table Twenty

Time, Error and Recall Data for Fifteen Subjects Engaged in Sequential Decision-Making for Track Three (H=3.72 bits)

Subject	Errors	Time In Seconds	Track Recall
1	41	705	.45
2	42	664	.52
3	42	1152	.20
4	38	828	.36
5	35	321	.50
6	30	933	.45
7	40	640	.25
8	36	398	.15
9	31	578	.60
10	33	402	.15
11	52	668	.28
12	44	683	.65
13	44	460	.33
14	39	458	.55
15	36	413	.20
Median	39	640	.36
Q	4.25	139.13	.31

Time vs Error - Rho=.16 (not significant .10 level)

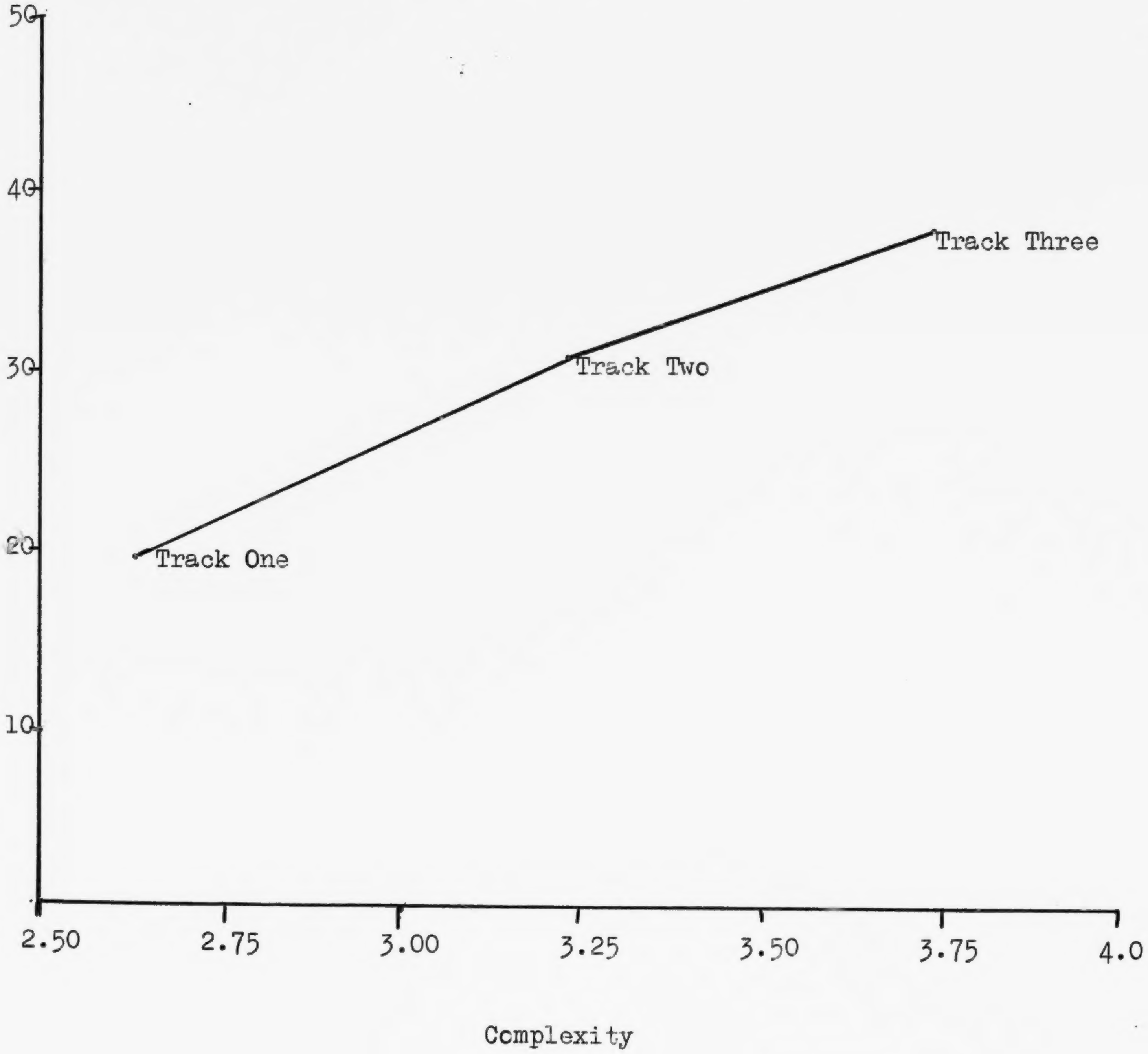

Figure Twelve. The relation between track complexity and prediction error. Based on sequential decision-making error (medians) for fifteen subjects on each track.

Rank-order correlations were computed between time to complete a track and total error. For the lowest level of complexity the value of Rho was .72; for the moderate level of complexity Rho was .39; and for the highest level of complexity the value of Rho was .16. This finding indicates that at the lower complexity levels it takes more time to produce a higher error score; but at the more complex level (producing nearly twice the number of errors produced at the lowest level) the correlation between time and error is not significant. Presumably, at the lower level of complexity, error is associated with a failure to detect the "redundancy" associated with the continuation of lines, regularity of angles, etc; while at the higher level of complexity there is "less to be learned." Under these conditions, variation in error performance is more surely a matter of chance no matter how much or little time is spent at each decision point. The time taken at a decision point is unrelated to errors when there is relatively little structure holding among decision points; but when there is more structure, time spent at a decision point is necessarily increased if the structure has not been detected by the decision-maker.

Although the effectiveness of immediate recall appears to be related to the level of complexity, the differences are not statistically significant at the .05 level. Again, the level of recall effectiveness is sufficiently low to support the operational possibility of using this measure as an index of a group's coactivity in the TDL context.

Given the constraints imposed on the subjects' decision-making procedures and the additional information provided in the instructions regarding the starting point and figure closure, the foregoing results are not at all surprising. Certainly there is little reason to expect significant departures from chance performance at the upper levels of track complexity. The potential value for the complexity quantifying approach described in this section is essentially methodological. The figures provide an alternate form of Vocom problems for use in either an experimental or the TDL setting, and they are ordered on a continuum of relative complexity as in the case of the "grain figures" described earlier. Conceivably the tracks used in the present investigation might be converted to solid figures, set in an appropriate matrix, and used for either experimental or training purposes in conjunction with either the discovery or the prediction operations described in the preceding sections. Presumably, the three tracks would again reveal a correlation with total error under either of these decision-making conditions. This conversion would be far less constraining on individual or team performance and therefore more useful in the training laboratory.

The data based on converting tracks to solid figures and using the discovery or prediction operations have not been gathered, but there seems to be quite good reason to expect the relation between error score and complexity to hold up under these conditions. (See Attneave and Parks.) In any case, the assumption needs to be tested.

Summary

The material presented in Section Three is largely a report of some preliminary considerations which are essentially methodological. Presumably, systematic inquiry concerning the process of human communication and the systematic development of meaningful strategies for communication training both depend on the conceptual model underlying both pursuits. In principle, the same conception may accommodate both activities, and both need to be based on empirical data relating to a number of parameters.

Given the conceptual outlines described in Section I, it is essential to gain objective observational access to the events about which the process of communication is to be studied, and one of the most important characteristics of such events is complexity, or structure. The effectiveness of enabling messages in a serial system of communication is surely influenced by the structure characterizing the referents of the messages; but exactly what form this influence may take cannot be determined without at least a crude measure of structure. Similarly, the internal problems and problem-solving behavior displayed by coactive groups is certainly influenced by the structure of the events in terms of which the initial problem is presented. Again, at least preliminary operations for assessing the complexity of the problem is a methodological essential. In this section we have described several working approaches to assessing complexity and some preliminary data relating selected performance measures to complexity level. The line of work reported has done far more to suggest what needs to be done than to provide solutions for research problems.

On the assumption that the effectiveness of enabling messages depends upon the fidelity with which the structure of referent events is replicated semiotically, it remains a fundamental research task to relate external structure to communicative effectiveness. And if this view has merit, it remains an even more fundamental task to develop useful operational approaches to structure and its experimental manipulation. As Garner has suggested, a search for both external and internal structure seems to be inherent in behavior (Garner, p. 339). Success in the undertaking seems, in addition, to be a necessary condition for man's well-being. Signs, systems of signs and the semiotic process constitute man's most distinguished solution to his problems of accommodating to the structure of his world and of generating new structures physically, biologically and socially. The process deserves more intensive study than it has received.

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